1.0 INTRODUCTION

The U.S. Forest Service (USFS), White River National Forest (WRNF), has initiated an Environmental Assessment (EA) for the Pandora Development and Summit Snowmaking projects at Aspen Mountain. Resource Engineering, Inc. (RESOURCE) has been retained to complete the watershed analysis required for the EA. This report describes the existing watershed condition of the project area; presents the analysis of potential effects to watershed resources; and outlines recommendations to avoid or minimize such effects.

2.0 FOREST PLAN DIRECTION

Pursuant to the 2002 Forest Plan, as amended, stream health management measures and design criteria are provided in the Region 2 Watershed Conservation Practices Handbook (WCPH) to ensure applicable Federal and State laws are met on National Forest System (NFS) lands in Region 2.[1] The Forest Plan and the WCPH direct how snowmaking and land treatments are to be managed in the White River National Forest.

2.1 MANAGEMENT AREA 8.25 – FOREST PLAN STANDARD

Standard 3. Snow management, including snowmaking and snow-farming, will be conducted in a manner that prevents slope failures and gully erosion, as well as bank erosion and sediment damage in receiving channels.

2.2 APPLICABLE WCPH MANAGEMENT MEASURES

The WCPH contains several Management Measures (MM) which are environmental goals to protect aquatic and riparian systems. MM of relevance regarding watershed resources are outlined below:

- MM-1. Manage land treatments to conserve site moisture and to protect long-term stream health from damage by increased runoff.
- MM-2. Manage land treatments to maintain enough organic ground cover in each activity area to prevent harmful increased runoff.
- MM-3. In the water influence zone (WIZ) next to perennial and intermittent streams, lakes, and wetlands, allow only those actions that maintain or improve long-term stream health and riparian ecosystem condition.
- MM-4. Design and construct all stream crossings and other instream structures to provide for passage of flow and sediment, withstand expected flood flows, and allow free movement of resident aquatic life.
- MM-5. Conduct actions so that stream pattern, geometry, and habitats maintain or improve long-term stream health.
- MM-8. Manage water use facilities to prevent gully erosion of slopes and to prevent sediment and bank damage to streams.

[1] USDA Forest Service, 2002; USDA Forest Service, 2005.

- MM-9. Limit roads and other disturbed sites to the minimum feasible number, width, and total length consistent with the purpose of specific operations, local topography, and climate.
- MM-10. Construct roads and other disturbed sites to minimize sediment discharge into streams, lakes, and wetlands.
- MM-11. Stabilize and maintain roads and other disturbed sites during and after construction to control erosion.
- MM-16. Apply runoff controls to disconnect new pollutant sources from surface and groundwater.

2.3 RELEVANT WCPH DEFINITIONS

Additionally, the WCPH provides definitions for some terms that are important to conveying information in this report:

Concentrated-Use Site: Areas designed and managed for high density of people or livestock, such as developed recreation sites and livestock watering areas.

Connected Disturbed Areas: (CDAs) High runoff areas like roads and other disturbed sites that have a continuous surface flow path into a stream or lake. Hydrologic connection exists where overland flow, sediment or pollutants have a direct route to the channel network. CDAs include roads, ditches, compacted soils, bare soils, and areas of high burn severity that are directly connected to the channel system. Ground disturbing activities located within the water influence zone should be considered connected unless site-specific actions are taken to disconnect them from streams.

Ephemeral Stream: A stream that flows only in direct response to precipitation in the immediate locality (watershed or catchment basin), and whose channel is at all times above the zone of saturation.

Hydrologic Function: The ability of a watershed to infiltrate precipitation and naturally regulate runoff so streams are in dynamic equilibrium with their channels and floodplains.

Intermittent Stream: A stream or reach of stream channel that flows, in its natural conditions, only during certain times of the year or in several years. It is characterized by interspersed, permanent surface water areas containing aquatic flora and fauna adapted to the relatively harsh environmental conditions found in these types of environments.

Gully: An erosion channel greater than 1 foot deep.

Perennial Stream: A stream or reach of a channel that flows continuously or nearly so throughout the year and whose upper surface is generally lower than the top of the zone of saturation in the areas adjacent to the stream.

Rill: An erosion channel less than 1 foot deep.

Stream Health: The condition of a stream versus reference conditions for the stream type and geology, using metrics such as channel geometry, large woody debris, substrate, bank stability, flow regime, water chemistry, and aquatic biota.

Stream Health Class: A category of stream health. Three classes are recognized in the Rocky Mountain Region: robust, at-risk and diminished. These classes are recommended to be used for assessing long-term stream health and impacts from management activities.

Stream Order: A method of numbering streams as part of a drainage basin network. The smallest unbranched mapped tributary is called first order, the stream receiving the tributary is called second order and so on.

Swale: A landform feature lower in elevation than adjacent hillslopes, usually present in headwater areas of limited areal extent, generally without display of a defined watercourse or channel that may or may not flow water in response to snowmelt or rainfall. Swales exhibit little evidence of surface runoff and may be underlain by porous soils and bedrock that readily accepts infiltrating water.

Water Influence Zone: The land next to water bodies where vegetation plays a major role in sustaining long-term integrity of aquatic systems. It includes the geomorphic floodplain (valley bottom), riparian ecosystem, and inner gorge. Its minimum horizontal width (from top of each bank) is 100 feet or the mean height of mature dominant late-seral vegetation, whichever is most.

3.0 AFFECTED ENVIRONMENT

3.1 PROJECT AREA DESCRIPTION

The scope of the analysis for the proposed Pandora Development and Summit Snowmaking projects focuses on watershed resources located on Aspen Mountain, both on NFS and private lands. A portion of the proposed Summit Snowmaking would be implemented on ski trails in the Spar Gulch watershed. The Pandora Development and the remaining portion of proposed snowmaking would be located within three watersheds drained by un-named tributaries to the Roaring Fork River. The paragraphs below provide a summary description of the study watersheds. **Figure A-1** (attached) is a vicinity map of the study watersheds.

3.1.1 Spar Gulch Watershed

The Spar Gulch Watershed is drained by a first-order stream tributary to the Roaring Fork River. Its channel was heavily impacted by mining and logging activities that occurred in the late 1800s and early 1900s, prior to the ski area development. These impacts include construction of the Summer Ditch which intercepts all Spar Gulch flows at an approximate elevation of 9,970 feet. The intercepted flows are then conveyed by the ditch to the west side of the mountain and discharged in the upper elevations of Keno Gulch, a natural drainage tributary to Castle Creek, tributary to the Roaring Fork River. The drainage area above the Summer Ditch (Upper Spar Gulch) totals 197 acres.

Spar Gulch flows as an intermittent stream from just below the Summer Road (at an elevation of approximately 10,250 feet) to the Summer Ditch. Downslope from the Summer Ditch, fill materials were

placed in the Spar Gulch channel (formerly known as "Prospector Drainage") apparently to facilitate the transport of logs harvested from the adjacent Bell Mountain. Additional grading activities took place in the 1950s to create the Spar Gulch ski trail that exists today. [2]

Currently, surface runoff originating downstream from the Summer Ditch flow in a steep, eroded channel that follows the fall line of the Spar Gulch ski trail. The stream is ephemeral at first, flowing only in response to snowmelt and after significant rainfall precipitation, and transitions to intermittent flow below the confluence with Copper Gulch at around 9,070 feet. At an elevation of approximately 8,470 feet the eroded channel flows into a series of 4 sediment traps constructed near the bottom terminal of the Bell Mountain chairlift. The sediment traps (built in series) discharge onto the forested slope located to the east (skiers' right) of the Little Nell ski trail. Field observations indicate that runoff flowing into the sediment traps infiltrates and continues as shallow groundwater until it re-surfaces at an elevation of approximately 8,150 feet, before discharging into the City of Aspen's storm sewer system, and ultimately into the Roaring Fork River. The drainage area of the Lower Spar Gulch Watershed (downstream from the Summer Ditch diversion) is 354 acres.

A total of 12,990 feet of drainage channels were mapped in the Spar Gulch watershed, including Copper Gulch, an ephemeral drainage which joins Spar Gulch downstream from the Summer Ditch, at an elevation of approximately 9,000 feet. **Figure A-2** is a map of the Spar Gulch Watershed which also shows the location of the Summer Ditch and Keno Gulch.

Annual precipitation in the Spar Gulch Watershed averages 26.5 inches of which approximately 50 percent occur as snowfall usually between the months of November and March.[3] Average monthly temperatures in the Spar Gulch Watershed range between 19 degrees F (December and January) and 59 degrees F (July).

3.1.2 Un-Named Tributary #1

The southeastern and back side sections of Aspen Mountain are located on slopes that drain through three un-named tributaries. For purposes of this study, we refer to these drainages as Tributary #1, #2, and #3 (see **Figure A-1**). The un-named Tributary #1 is adjacent to the Spar Gulch Watershed and contains the lower elevations of the existing Lud's Lane and North Star ski trails, as well as the existing Gents Pond #1. Except for the uppermost elevations where the aforementioned ski area infrastructure exists (above 10,120 feet), the Tributary #1 watershed slopes are well vegetated with conifers and aspen trees. A steep ephemeral channel drains this 257-acre watershed to an elevation of approximately 8,150 feet where the slope flattens and the stream becomes perennial, flowing through a wetlands complex before discharging in the Roaring Fork River.

[2] Gerdin V., 2018.
[3] PRISM Climate Group; NRCS, 2018.

3.1.3 Un-Named Tributary #2

The top of Aspen Mountain, along with the Walsh's, Hyrup's, and Kristin ski trails are located in the un-named Tributary #2 Watershed. It extends from an elevation of 11,212 feet at the top of Aspen Mountain to approximately 8,020 feet at its confluence with the Roaring Fork River. No activities have been implemented in the watershed below 10,240 feet of elevation. An ephemeral stream drains this watershed, which includes slopes forested with conifers and aspen trees. The surface area of the un-named Tributary #2 watershed is 386 acres.

3.1.4 Un-Named Tributary #3

This 372-acre watershed is spans from the ridge between the top of Aspen Mountain and Richmond Hill at approximately 11,372 feet to 8,030 feet at its discharge point on the Roaring Fork River. The watershed is essentially undisturbed, except for sections of two mountain roads that traverse across the watershed at a gentle slope: (1) a 2,500-foot section of the Richmond Hill Road located at the highest elevations of the watershed; and (2) a private road approximately 2,380 feet long that provides access to the Loushin Springs and Pond just above 10,400 feet of elevation. The watershed is drained by an ephemeral/intermittent stream that runs through steep slopes forested with conifers and aspen trees.

Precipitation and temperature data for the three un-named tributaries are essentially the same, receiving on average 26.8 inches of precipitation per year, with average monthly temperatures between 19.5 (December) and 59.7 degrees F (July).[4]

3.2 WATERSHED CONDITION

Watershed condition can be defined in terms of geomorphic, hydrologic, and biotic integrity, as compared to its potential natural condition. Within the scope of this analysis, geomorphic integrity relates to the watershed's channel morphology, soil erosion, slope stability, and other physical characteristics of aquatic habitats; hydrologic integrity or functionality can be determined based upon flow, sediment, and water quality characteristics.[5] Stream health surveys are typically completed as part of watershed condition assessments, using metrics such as percentage of unstable banks, density of large woody debris, and fine sediment deposits on the stream bed. However, because there are no perennial streams located in the project area, stream health surveys following the standard USFS protocols (such as the R1/R4 Fish and Fish Habitat Standard Inventory Procedures Handbook[6]) are not applicable for this project. Spar Gulch upstream of the Summer Ditch is an intermittent stream that flows adjacent to wetlands in some areas, and that only conveys water during the snowmelt season and after intense precipitation events. Below the Summer Ditch, Spar Gulch is an ephemeral drainage channel eroded in fill materials. Within the project

[4] Ibid.
[5] USDA Forest Service, 2011a.
[6] Overton et al., 1997.

area, the Roaring Fork River tributaries 1, 2, and 3 are all ephemeral streams.

In order to objectively evaluate the condition of the study watersheds, this report follows the approach outlined in the USFS-developed Watershed Condition Classification (WCC). The WCC Technical Guide describes the classification procedure which is typically done for 6th-level hydrologic unit (about 10,000 to 40,000 acres in size)[7] and is therefore not applicable at the scale of the study watersheds. However, the indicators outlined in the WCC Guide are relevant for analysis and discussion of the condition of smaller watersheds and provide a systematic approach to describe the condition of the study watersheds. This assessment is not intended to amend or supplement the 6-th level watershed classification completed by the USFS; it is only utilized to describe the existing condition of the study watersheds within the context of the analysis of potential effects that would result from implementation of the proposed projects.

. This report focuses on the following physical indicators of watershed condition: (i) Water Quality; (ii) Water Quantity; and (iii) Roads and Trails. Each indicator receives a rating, based on the criteria outlined in the WCC Guide and professional judgement. A summary description of the possible ratings is included in **Table 1**.

Table 1

Watershed Condition – Description of Ratings

Condition Rating 1	"GOOD" condition. Expected in a watershed with high geomorphic, hydrologic, and biotic integrity relative to its natural potential condition. This rating indicates the watershed is functioning properly with respect to the rated attribute.
Condition Rating 2	"FAIR" condition. Expected in a watershed with moderate geomorphic, hydrologic, and biotic integrity relative to its natural potential condition. This rating suggests the watershed is functioning at risk with respect to the rated attribute
Condition Rating 3	"POOR" condition. Expected in a watershed with low geomorphic, hydrologic, and biotic integrity relative to its natural potential condition. This rating indicates the watershed is impaired with respect to the rated attribute.

3.2.1 Water Quality

Impaired Waters (303(d) listed)

Section 303(d) of the Clean Water Act (CWA) requires that States prepare a list of water quality-limited, or impaired, stream segments. Specifically, Section 303(d) of the CWA requires States to submit to the U.S. Environmental Protection Agency (EPA) a list of "those waters for which technology-based effluent limitations and other required controls are not stringent enough to implement water quality standards." The States then conduct an analysis to determine total maximum daily loads (TMDL) for the water bodies

[7] USDA Forest Service, 2011b.

included in this list, commonly referred to as 303(d) List. The TMDL analysis determines the amount of a specific pollutant that can be discharged in a water body without causing the corresponding water quality standard to be exceeded.

The upper reaches of the Roaring Fork River, from its headwaters to a point just downstream from its confluence with Hunter Creek[8] have been given the Water Body Identification (WBID) COUCRF02_A by the State of Colorado's Water Quality Control Commission. This segment of the Roaring Fork River include the study watersheds and are classified for Agricultural, Aquatic Life Cold 1, Recreation E (existing), and Water Supply uses. Numeric water quality standards for physical and biological parameters, and for various metals and inorganic compounds, have been implemented for this segment of the Upper Colorado River Basin.[9] Also in compliance with requirements of the CWA, the State of Colorado issued its most recent Integrated Water Quality Monitoring and Assessment Report in 2018.[10] In summary, these periodic assessments are conducted by comparing water quality data of surface waters throughout Colorado against the corresponding standard. The Report classified WBID COUCRF02_A under Category 3b: Segment placed on the Monitoring and Evaluation List (M&E List) for dissolved Copper. This means that there is insufficient data to support an attainment determination for any classified use, thus supplementary data and monitoring is required to complete the assessment. In other words, the available data indicates that there may be an impairment but there is not enough data to put it on the 303(d) list. Segments are placed on the M&E List until additional data can be collected to either add it to the 303(d) list (Category 5: Not meeting applicable water quality standards for one or more classified uses), or place it into Category 1 (Attaining water quality standards for all classified uses.)

Water Quality Problems

No water quality problems have been identified for the three un-named tributaries to the Roaring Fork River. However, evidence of high sediment loads has been documented for the Spar Gulch watershed. For example, areas of erosion adjacent to the Spar Gulch channel have been observed (see **Photos 1-2**).

The Spar Gulch channel flows through a series of sediment traps (which are periodically cleaned) before discharging into the City of Aspen's storm sewer system before discharging into the Roaring Fork River. It is not known how much of the Spar Gulch sediment, if any, reaches the Roaring Fork River. The Spar Gulch sediment loading could be reduced by improving the existing sediment traps and implementing standard Best Management Practices (BMPs) for sediment and erosion control (see Section 4.2.4). Therefore, the Spar Gulch watershed is rated as Fair ("… *localized incidence of accelerated sediment*…"). **Table 2** shows the ratings assigned to the study watershed for the Water Quality indicator.

[8] Except all tributaries within the Collegiate Peaks and Hunter/Frying Pan Wilderness Areas.
[9] CDPHE, 2018a.
[10] CDPHE, 2018b.

Photo 1

Spar Gulch Trail culvert discharge into the Spar Gulch channel
(Just up-slope from Bell Mountain lower terminal)

Photo 2

Lateral erosion on Spar Gulch channel
(Just up-slope from Bell Mountain lower terminal)

Table 2

Water Quality Indicator Ratings for Study Watersheds

Watershed	Water Quality Rating
Spar Gulch	FAIR: No State-listed impaired or threatened water bodies (but on M&E List); the watershed has moderate water quality problems (localized incidence of accelerated sediment.)
Tributary #1	GOOD: No State-listed impaired or threatened water bodies (but on M&E List); the watershed has minor or no water quality problems.
Tributary #2	GOOD: No State-listed impaired or threatened water bodies (but on M&E List); the watershed has minor or no water quality problems.
Tributary #3	GOOD: No State-listed impaired or threatened water bodies (but on M&E List); the watershed has minor or no water quality problems.

3.2.2 Water Quantity

Yield of the study watersheds was estimated following the methodologies presented in the WRENSS Procedural Handbook,[11] as updated by Troendle, Nankervis, and Porth,[12] and supplemented by the Colorado Ski Country USA (CSCUSA) Handbook.[13] In summary, the WRENSS Model generates a water balance using seasonal precipitation and vegetation type and density (distributed by watershed aspect) and then computes the amount of water potentially available for runoff. The water balance of the WRENSS Model is coupled with a snowmaking hydrology computation process developed through the CSCUSA study. Together, these calculations produce estimates of water yield typical of subalpine mountain watersheds. The WRENSS Model distributes the calculated annual yield using simulated hydrographs based on data recorded at various streamflow gaging stations. The simulated hydrographs represent the normalized distributions of the annual yield in 6-day intervals throughout the year. It is important to note that the computations do not include routing of runoff water through the watershed to the stream system. Thus, water yield hydrographs do not represent actual streamflow, but rather a time distribution of basin-wide water yield available to the receiving waters. The WRENSS hydrologic model was developed to simulate expected changes in streamflow as the result of silvicultural activities, not streamflow itself.

One of the applications of the WRENSS model is to compare computations of watershed yield and 6-day average peak flows between different watershed conditions. Baseline (or pre-development) conditions in the study watersheds were estimated based upon un-developed watersheds of similar characteristics (e.g. acreage, elevation, aspect) in the vicinity. Of the study watersheds, Spar Gulch is by far the most impacted

[11] EPA, 1980.
[12] Troendle et al., 2003.
[13] Colorado Ski Country USA, 1986.

by anthropogenic activities (mining and logging first, ski area development, including snowmaking applications in more recent years). On the other hand, the Tributary #3 watershed is the least affected by development. **Table 3** summarizes the acreage of forests in the study watersheds under baseline and existing conditions.

The water yields, expressed in acre-feet (AF), and peak flows -in cubic feet per second (cfs)- calculated using the WRENSS Model are summarized in **Table 4**, for both baseline and current conditions, and assuming average precipitation and temperatures. Hydrograph plots that depict the temporal distribution of the computed water yields were also developed for the study watersheds, using the WRENSS Model (see **Figure 1**). These modeled hydrographs reveal the different flow characteristics of baseline and existing conditions in watersheds where tree clearing and snowmaking have occurred. In general, snowmelt hydrographs influenced by vegetation clearing have higher intensity peak flows that occur earlier in the runoff season as compared to pre-development, or baseline conditions. This is a direct consequence of the higher volume and rate of snowmelt due to decreased canopy interception and evapotranspiration, increased solar radiation in cleared areas, and also due to the snowmaking water input (where applicable). On the other hand, man-made snow production, as well as snow compaction by skier traffic and grooming operations, can cause a delay in the start of the snow melting process. Although this effect has been observed and documented at many ski areas, an accepted procedure to calculate with certainty the behavior of artificial and/or compacted snow has not been developed. The CSCUSA Handbook[14] provides a monthly time distribution of snowmelt runoff for ski trails with and without snowmaking applications. Six time distributions are included in the CSCUSA Handbook for different ski areas in Colorado and for typical dry, average, and wet years. The “Snowmass” time distribution would apply to the study watersheds as Snowmass ski area is closest and its ski trails are at similar elevations. The CSCUSA study found that at Snowmass a 4-week delay occurs for a portion of the runoff originating in ski trails with man-made snow. A more recent investigation in central Switzerland also found a 4-week delay in snowmelt due to ski-slope grooming and artificial snow production.[15] For purposes of this study, we assume that man-made snow begins to melt, on average, 4 weeks later than natural snow.

Yield and peak flows where computed at two locations for Spar Gulch: (1) at the point where the Summer Ditch currently intercepts Spar Gulch flows; and (2) at a point where Spar Gulch discharges into the City of Aspen’s storm sewer system. For the three un-named watersheds, the yield and peak flows were computed at the points where the watersheds flow into the Roaring Fork River.

It is important to note that watershed yield and streamflow values shown in **Table 4** and **Figure 1** correspond to average conditions of precipitation and temperature. Most of the water supply for watersheds in the Colorado Rocky Mountains comes from the snowpack which accumulates during the winter and melts

[14] Ibid.
[15] Keller T. et al., 2004.

in summer. Both of these processes, the accumulation of snow and its subsequent melt, can vary significantly from year to year, depending upon several factors in addition to the spatial and temporal distribution of precipitation and temperatures; for instance cloud cover, soil moisture, and occurrence of wind.[16,17] Therefore, the annual yield and streamflow patterns can also differ from one year to the next. For example, yields and peak flows were computed for typical dry and wet years such as 2012 and 2011 for the Spar Gulch watershed. In these examples, the wet year watershed yield was 55% higher than the average, while the dry year yield was calculated at 29% lower than the average. **Figure 2** displays the 6-day hydrographs and **Table 5** compares the modeled water yields and peak flows of the Spar Gulch watershed for temperatures and precipitation corresponding to the typical dry, average, and wet years.

Table 3

Study Watersheds – Summary Description of Study Watersheds

Watershed	Drainage Area (acres)	Baseline Forests (acres)	Existing Forests	
			(acres)	(% of Baseline)
Spar Gulch	551	495	232	47%
Tributary #1	257	246	216	88%
Tributary #2	386	363	308	85%
Tributary #3	372	346	331	96%

Table 4

WRENSS Model Output for Baseline and Existing Conditions (Average Year)

Watershed	Baseline		Existing	
	Water Yield (AF)	Peak Flow (cfs)	Water Yield (AF)	Peak Flow (cfs)
Spar Gulch at Summer Ditch	70	0.6	211	2.3
Spar Gulch at City of Aspen	228	2.2	328	3.3
Tributary #1	117	1.2	147	1.4
Tributary #2	166	1.7	218	2.1
Tributary #3	141	1.4	155	1.5

[16] Chow V.T., Maidment D.R., and Mays L.W., 1988.
[17] Eagleson P.S., 1970.

Table 5

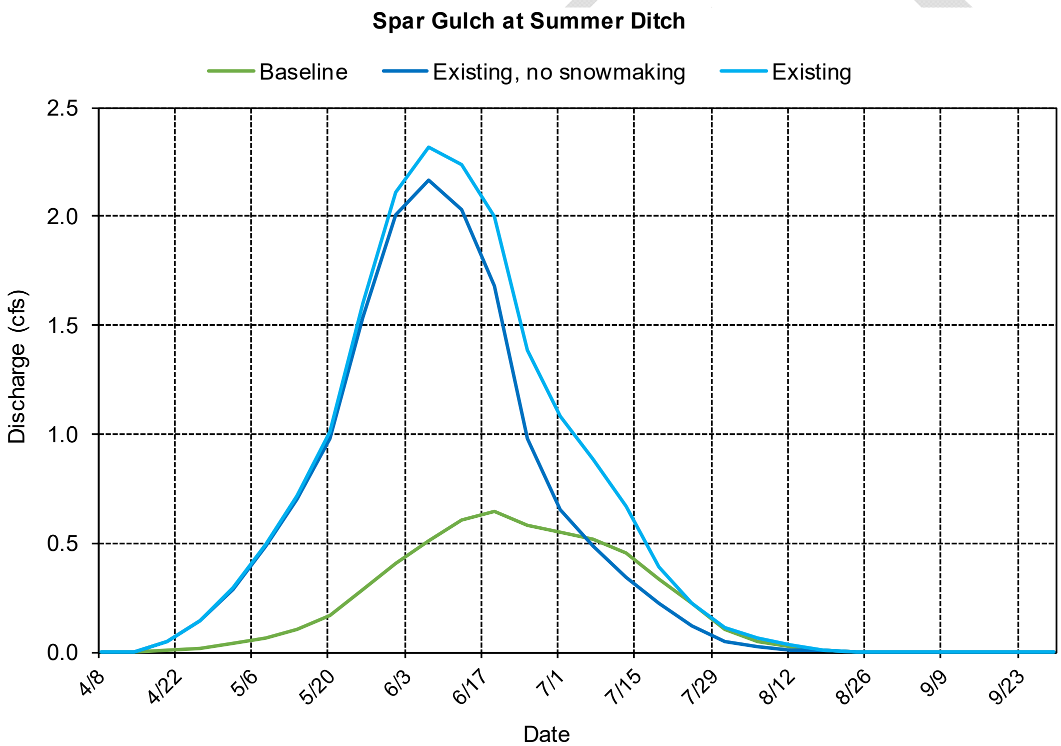
Comparison of Watershed Yield and Peak Flows - Dry, Average and Wet Conditions

Parameter	Dry		Average	Wet	
	Amount	% Change		Amount	% Change
Spar Gulch at City of Aspen Yield (AF)	232	-29%	328	506	+55%
Spar Gulch at City of Aspen Peak Flow (cfs)	2.3	-29%	3.3	5.0	+54%

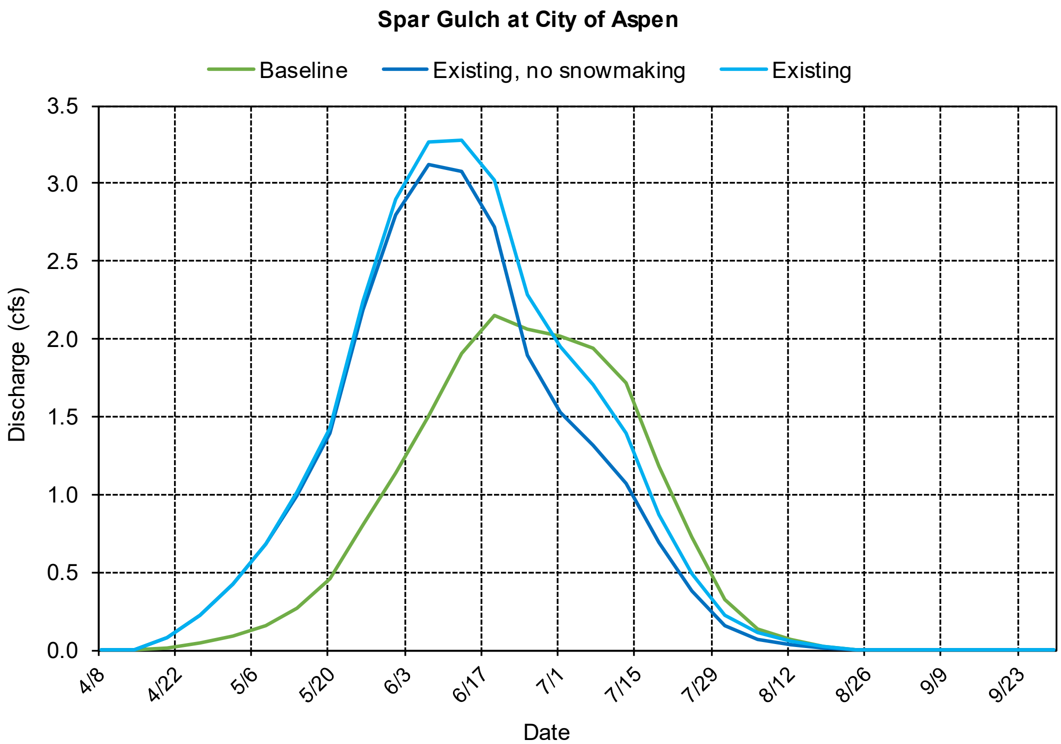
Figure 1

Temporal Distribution of Streamflows
Baseline and Existing Conditions with and without Snowmaking

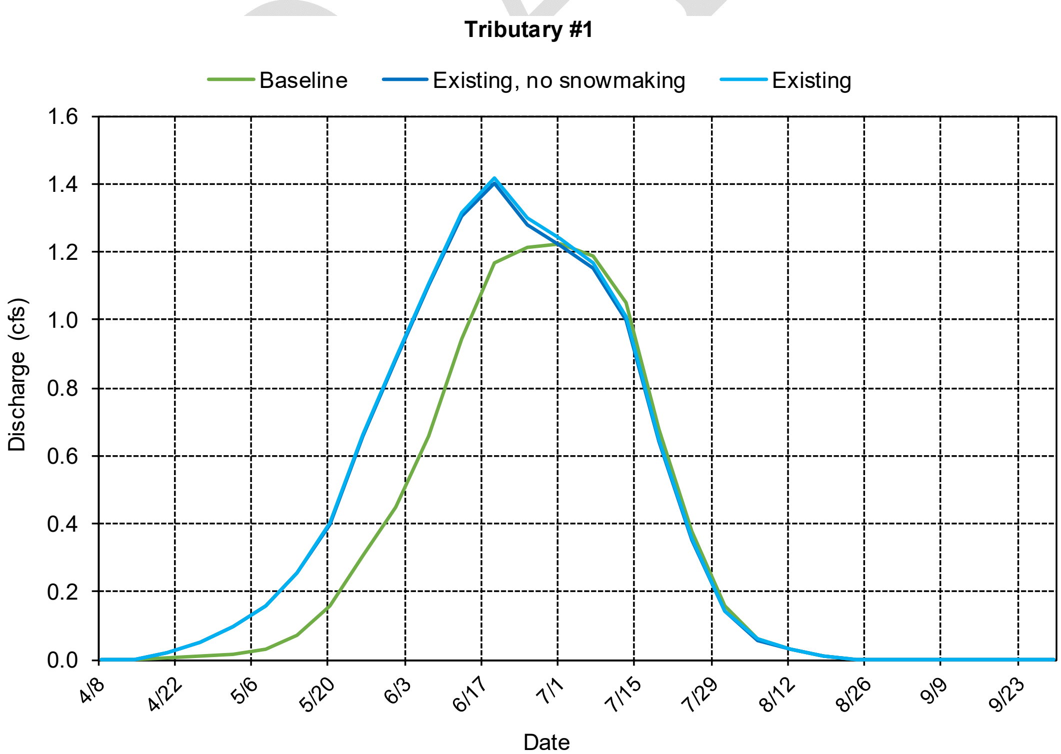
Plot 1.1



Plot 1.2

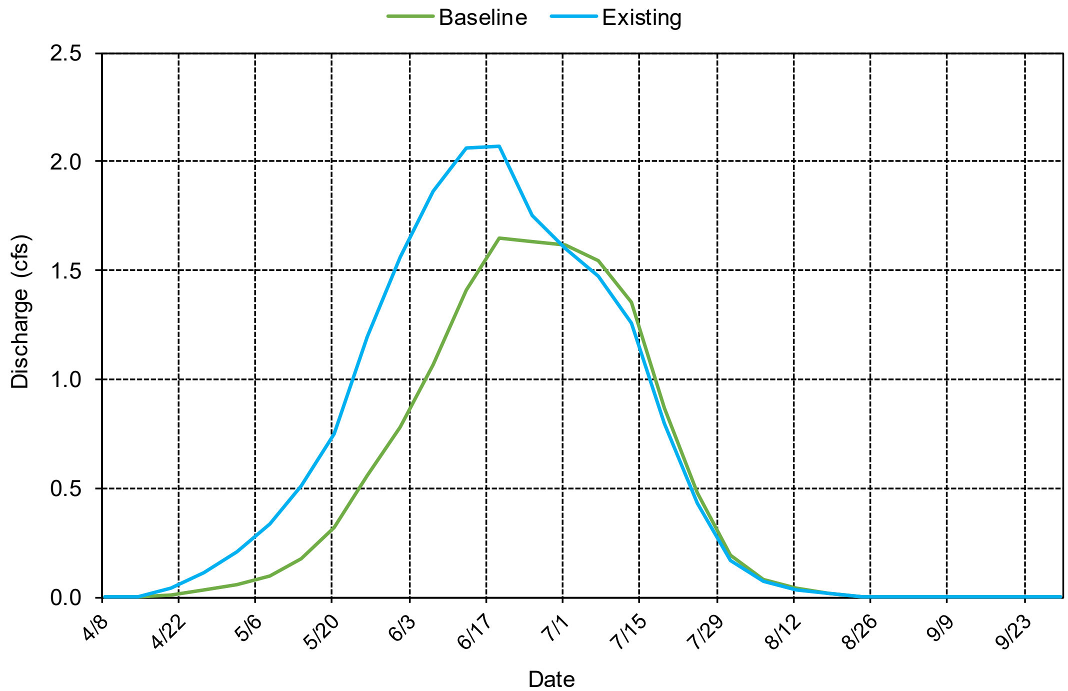


Plot 1.3



Plot 1.4

Tributary #2



Plot 1.5

Tributary #3

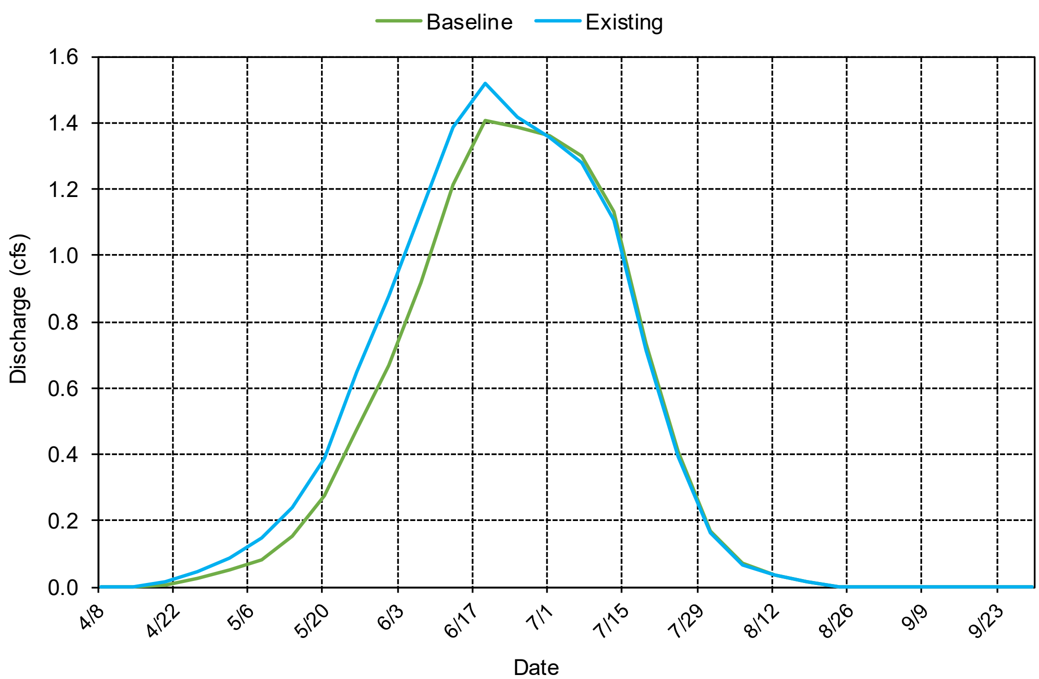
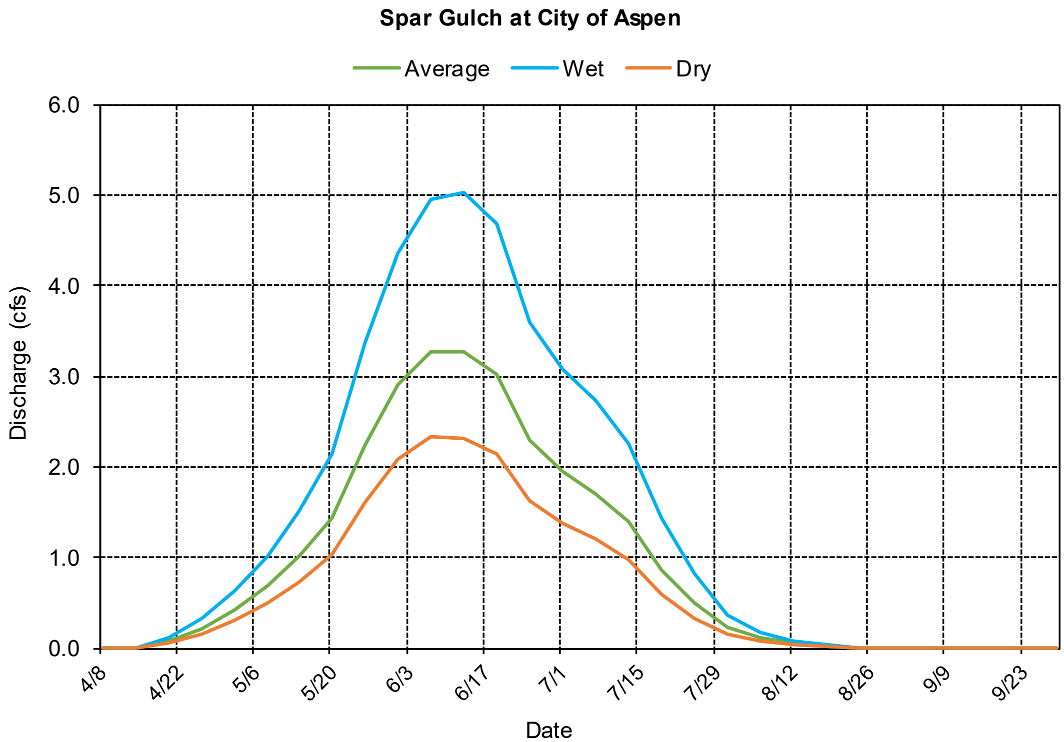


Figure 2

Comparison of 6-day hydrographs computed for Spar Gulch under Wet, Dry, and Average conditions.



Based upon the comparison between computed water yields and hydrographs presented above, and on guidance outlined in the WCC Guide, the Water Quantity indicator was rated for the study watersheds as summarized in **Table 6**. For example, the Spar Gulch yield and hydrograph are greatly impacted by the Summer Ditch diversions, extensive tree clearing and snowmaking applications. The magnitude and timing of Spar Gulch flows show a substantial departure from natural (baseline) conditions. On the other hand, the three un-named tributaries show only minor departure from baseline conditions and are therefore rated as Good.

Table 6

Water Quantity Indicator Ratings for Study Watersheds

Watershed	Water Quality Rating
Spar Gulch	Poor: The magnitude, duration, and/or timing of annual extreme flows (low and/or high) significantly depart from the natural hydrograph.
Tributary #1	Good: Stream hydrographs have no or minor departure from natural conditions.
Tributary #2	Good: Stream hydrographs have no or minor departure from natural conditions.
Tributary #3	Good: Stream hydrographs have no or minor departure from natural conditions.

Estimation of Streamflow Values by Other Computational Models

As part of a field investigation completed by RESOURCE in the summer of 2011, a Parshall flume was installed in the Spar Gulch channel some 1,200 feet up-slope from the Summer Ditch. The flume's staff gage was read daily (and often twice a day) during the June 13 through July 6 period to better estimate the volume and rate of flow of Spar Gulch at this location. Although limited, this data set provides valuable information; it shows instantaneous streamflow values as high as 2.4 cfs and daily averages up to 1.65 cfs on June 16, with flow rates receding to between 0.1 and 0.2 cfs by early July. The 6-day average streamflow in mid-June was observed to be approximately 1.4 cfs. The data indicates that in 2011 flows had already peaked by mid-June at this location. Considering that the area draining at the location of the flume is 70 acres, or about 35 percent, smaller than the Upper Spar Gulch watershed, these field observations show that the Spar Gulch streamflows values computed with the WRENSS model are reasonable (see **Table 4** and **Figure 4**, Plot 1.1).

As stated above, one of the advantages of the WRENSS model is that it allows the user to simulate expected changes in watershed yield and streamflow distribution that would result from implementation of activities proposed for the watershed (e.g. water yield before and after tree clearing). Therefore, the WRENSS model is often used as a tool to estimate the effects of ski area projects, such as trail construction and/or snowmaking, on a watershed. Other tools and procedures should be used to estimate instantaneous peak flood values.

For instance, WRC computed estimates of Spar Gulch peak-flood values for various recurrence intervals as part of the analysis completed for the City of Aspen's Surface Drainage Master Plan.[18] WRC used the EPA Storm Water Management Model (SWMM) to calculate peak flow values that would result from runoff associated with intense rainfall events with return periods ranging from 2 to 100 years (see **Table 7**). The WRC study conservatively assumed that all surface runoff in the Spar Gulch watershed would reach the City's storm sewer system (this is, as if the Summer Ditch did not exist). The WRC SWMM model calculated the Spar Gulch instantaneous peak flow produced by a rainstorm with a 50% chance of occurrence (i.e. the 2-year peak-flood) at 70 cfs, while the 10-year peak flow was computed at 155 cfs.

The WRC analysis also included estimations of peak flows generated by snowmelt in the Spar Gulch watershed. WRC computed snowmelt using the US Army Corps of Engineers HEC-1 model with temperature data obtained from the Aspen and Aspen 1 SW weather stations. Note that these stations are located near the bottom of Aspen Mountain, at elevations of 7,928 feet and 8,175 feet respectively. Therefore, snowmelt computed for Aspen Mountain using this data may have yielded conservative results. WRC reports an annual average peak flow (including man-made snow) of 10 cfs at the point where Spar Gulch discharges into the City's storm drainage system. This value compares favorably with the 5.6 cfs 6-day annual average peak computed by WRENSS for the whole Spar Gulch watershed (Upper and Lower

[18] WRC, 2001.

combined). The HEC-1 model computation of the 10-year snowmelt (including snowmaking) is 17 cfs.

The US Geological Survey (USGS) has developed StreamStats, a web application that computes streamflow statistics at user-selected sites by using regression equations for the hydrological region of interest. The 2-year instantaneous peak-flow computed for the full Spar Gulch watershed using StramStats equals 14.4 cfs; and the 10-year peak flow is 25.5 cfs. The 7-day maximum flow corresponding to the 2-year flood is 8.1 cfs. Note that computation of streamflow statistics using StreamStats in the Mountain Hydrologic Region of Colorado (where Aspen Mountain is located) is recommended for sites with drainage areas between 1 and 1,060 square miles.[19] The Spar Gulch watershed, from its highest elevation at the top of Aspen Mountain to its discharge point at the City of Aspen measures approximately 550 acres, or 0.86 square miles, and it is therefore outside of the StreamStats recommended range. **Table 7** compares the peak flows computed for the full Spar Gulch watershed using different computational models for different events (e.g. snowmelt, intense rainfall) and recurrence intervals. Appendix A contains a copy of the report generated by StreamStats for the Spar Gulch Watershed. A copy of the WRC report is in the project file.

Table 7

Comparison of Peak Flows Computed for the Full Spar Gulch Watershed using Different Procedures

Parameter	Discharge (cfs)
WRENSS (average year, 6-day maximum)	5.6
HEC-1 (average year, peak value)	10.0
StreamStats (2-year, 7-day maximum)	8.1
StreamStats (2-year, instantaneous peak)	14.4
SWMM (2-year rainfall event, instantaneous peak)	70.0
StreamStats (10-year, instantaneous peak)	25.5
SWMM (10-year rainfall event, instantaneous peak)	155.0

3.3.3 Roads and Trails

The Roads and Trails indicator addresses changes to the hydrological regime due to the density, state, and proximity to water of the road and trail network. Roads contribute more sediment to streams than any other land use; in addition, roads (and other linear features such as trails) can alter the hydrologic regime by, for instance, expanding the length of the channel network within the watershed, which in turn increases

[19] Capesius, J.P. and Stephens V.C., 2009.

efficiency of flow routing within the watershed, increasing peak flows and altering their timing.

Open Road Density

The WCC Guide uses the 1 mile per square mile (mi/mi^2) as the maximum road and trail density for a Good, or functioning properly, rating. Watersheds with road densities between 1 and 2.4 mi/mi^2 are considered as Fair, while road densities of more than 2.4 mi/mi^2 lead to a Poor rating for this attribute. These rating guidelines were derived from U.S. Fish and Wildlife Service guidance developed for a large geographical area of the Western U.S. and the WCC Guide states that they may be adapted to reflect local conditions. The Forest Plan does not include standards or thresholds for road densities in a watershed; thus, for purposes of this study, the WCC guidelines are used to determine the attribute rating. As shown in **Table 8**, only the Tributary #1 watershed scores Good for this attribute, while the remaining study watersheds are rated as Poor.

Table 8

Open Roads Density Ratings for Study Watersheds

Watershed	Drainage Area (mi^2)	Length of Roads and Trails (miles)	Density (mi/mi^2)	Rating
Spar Gulch	0.86	6.12	7.11	Poor
Tributary #1	0.40	0.11	0.28	Good
Tributary #2	0.60	1.87	3.10	Poor
Tributary #3	0.58	1.56	2.69	Poor

Road and Trail Maintenance

This attribute is rated based on the percent of roads and trails where adequate BMPs have been implemented to maintain proper drainage conditions. RESOURCE completed an inspection of Aspen Mountain roads during site visits on May, July, and August of 2018. Although the main mountain road (County Road 14, aka Summer Road) was observed to be well maintained, its drainage features (road culverts and ditches, waterbars) did not include BMPs. The secondary roads, used for maintenance of ski area facilities, were also generally well maintained. However, the steep Spar Gulch trail which is periodically used as a road for operations and maintenance of the snowmaking and chair lift infrastructure, is in poor condition: absence of BMPs for erosion and sediment control; ruts on the road surface; road culverts partially blocked with road sediment; waterbars or relief culverts not properly spaced. In summary, "BMPs for the maintenance of drainage features are applied to less than 50 percent of the roads and trails in the watershed. Thus, this attribute is rated as Poor for all of the study watersheds (**Photos 3-5** and **Table 9**).

Table 9

Road and Trail Maintenance Ratings for Study Watersheds

Watershed	Percent of Roads and Trails with BMPs	Rating
Spar Gulch	< 50%	Poor
Tributary #1	< 50%	Poor
Tributary #2	< 50%	Poor
Tributary #3	< 50%	Poor

Photo 3

View of County Road 14 in near the base of Aspen Mountain.

Photo 4

View of County Road 14 in the Spar Gulch watershed looking towards the Deer Park trail.

Photo 5

View of Spar Gulch Road approximately 770 feet downslope from Lift 3 bottom terminal
Note ruts on road and eroded waterbar (discharge into Spar Gulch channel)

Proximity to Water (Connected Disturbed Areas)

Roads and trails are usually a primary source of channelized connection between disturbed soils and the stream channel. Because road/trail drainage ditches provide an efficient mechanism for capturing runoff and frequently drain to a stream system, a direct link between the sediment source and the stream system is easily created. This attribute of the Roads and Trails indicator is rated based upon the percentage of roads and trails within 300 feet of streams and water bodies, or that are hydrologically connected to them (i.e. are Connected Disturbed Areas, or CDAs). Road and trail drainages frequently connect directly to the stream channel and result in a net increase in the length of the existing channel network within the watershed. This increases the efficiency of flow routing within the watershed, increasing peak flows and subsequent erosion and sediment transport.

Roads and other disturbed sites, having a continuous surface flow path into a stream or lake are defined as CDAs.[20] On Aspen Mountain, roads and trails exist in proximity of the study watersheds' drainage channels; however, these are intermittent and ephemeral streams and a "continuous surface flow path" to a perennial stream was not identified for any of the study watersheds. Therefore, the concept of CDAs is not fully applicable.[21] For purposes of this analysis, however, CDAs and the proximity to water attributes were computed as a means to assess the condition of the study watersheds. As shown in **Table 10** only the Spar Gulch watershed has roads and trails within 300 feet of its drainage channel. **Table 11** shows the CDAs identified in the study watersheds.

Table 10

Proximity to Water Ratings for Study Watersheds

Watershed	Percent of Roads and Trails within 300 ft of Channel	Rating
Spar Gulch	31%	Poor
Tributary #1	0%	Good
Tributary #2	0%	Good
Tributary #3	0%	Good

[20] USDA Forest Service, 2005.
[21] USDA Forest Service, 2018.

Table 11

Connected Disturbed Areas in the Study Watersheds

Watershed	CDAs (acres)
Spar Gulch	3.1
Tributary #1	0.0
Tributary #2	0.0
Tributary #3	0.0

Mass Wasting

Ratings to this attribute are given based upon a semi-quantitative determination of roads located on "unstable landforms or rock types subject to mass wasting". A GIS analysis shows that none of the existing roads and trails are within soil map units with high potential for mass movement.[22] However, there have been various events of erosion and slope failure within and adjacent to the study watersheds.[23] In addition, evidence of road sediment being delivered to the drainage channel was observed in the Spar Gulch watershed. Although the Spar Gulch channel is not a live stream, but an intermittent drainage, the amount of road sediment conveyed by it is a concern in this watershed. Therefore, this attribute is classified as Poor for the Spar Gulch watershed, and Good for the remaining study watersheds (see **Table 12**).

Table 12

Mass Wasting Ratings for Study Watersheds

Watershed	Roads on Unstable Landforms	Past Slope Stability Events	Sediment Loading to Stream Channel	Rating
Spar Gulch	None	Yes	Substantial	Poor
Tributary #1	None	No	None observed	Good
Tributary #2	None	No	None observed	Good
Tributary #3	None	No	None observed	Good

[22] USDA Forest Service, 1995.
[23] McCalpin, 2010.

Roads and Trails Rating

Based upon the scores given to the attributes discussed above, the Roads and Trails indicator was rated for the study watersheds under current conditions. As shown in **Table 13**, Spar Gulch rated Poor; the Tributary #1 watershed rated Good; and the remaining two study watersheds were classified as Fair for the Roads and Trails indicator.

Table 13

Roads and Trails Scoring for Study Watersheds

Watershed	Spar Gulch	Tributary #1	Tributary #2	Tributary #3
Density	Poor: 3	Good: 1	Poor: 3	Poor: 3
Maintenance	Poor: 3	Poor: 3	Poor: 3	Poor: 3
Proximity to Water	Poor: 3	Good: 1	Good: 1	Good: 1
Mass Wasting	Poor: 3	Good: 1	Good: 1	Good: 1
Rating	**Poor: 3**	**Good: 1.5**	**Fair: 2.0**	**Fair: 2.0**

3.3.4 Existing Watershed Condition

As stated before, the WCC typically applies to watersheds at the 6-th HUC level, and classification is computed as a weighted average of the twelve indicators (physical and biological). This report assessed three of the five physical indicators (Aquatic Habitat was determined to be non-applicable, and the soils resource is not within the scope of work for this report); **Table 14** summarizes the scores assigned to each study watershed.

Table 14

Scores of Physical Indicators for the Study Watersheds

Watershed	Spar Gulch	Tributary #1	Tributary #2	Tributary #3
Water Quality	Fair: 2	Good: 1	Good: 1	Good: 1
Water Quantity	Poor: 3	Good: 1	Good: 1	Good: 1
Roads and Trails	Poor: 3	Good: 1	Fair: 2	Fair: 2

The three physical indicators analyzed and discussed above provide information relevant to the condition of the study watersheds. In summary, the Spar Gulch watershed appears to be in less than Good condition and perhaps close to a Poor classification at least in terms of physical indicators. The available data

suggests that the Spar Gulch watershed has low hydrologic integrity relative to its natural potential condition. The three un-named tributaries to the Roaring Fork River subject to this study, however, appear to be in Good condition and functioning properly (i.e. they have high hydrologic integrity.)

4.0 DIRECT AND INDIRECT ENVIRONMENTAL CONSEQUENCES

4.1 ALTERNATIVE 1 – NO ACTION

Under the No Action Alternative, the existing management practices at Aspen Mountain would continue without changes, additions, or upgrades. The Aspen Skiing Company (ASC) would continue its current summer and winter operations. Removal of vegetation, terrain grading, and/or implementation of additional snowmaking would not result from selection of this alternative. Alternative 1 would have no direct or indirect effects on the watershed resources and the study watersheds would continue to exhibit the condition scores presented in Section 3.2 and summarized in **Table 14** above.

4.2 ALTERNATIVE 2 – PROPOSED ACTION

A detailed description of the proposed projects will be included in Chapter 2 of the EA. Projects proposed under Alternative 2 include installation of a new chairlift (the Pandora Lift), creation of 180 acres of trails and gladed terrain, and construction of additional snowmaking infrastructure on 53 acres of existing ski trails located near the top of Aspen Mountain. The proposed snowmaking infrastructure also involves construction of two new storage ponds with an estimate capacity of 16.15 acre-feet. Construction of the new Pandora Lift would require 6.7 acres of tree clearing and grading for construction of terminal stations and a new maintenance access road. A temporary construction access road would be graded along an approximately 3,000-foot-long existing, abandoned mining road; this construction access road would be reclaimed to original grade and revegetated following construction. The new ski terrain would include 101 acres of gladed trails and 79 acres of traditional ski trails. In total, approximately 65 acres of tree cut and 101 acres of glading (tree thinning) would be required for completion of the Proposed Projects.

4.2.1 Water Quality

The primary potential effects to water quality associated with the proposed activities would be:

(1) Effects of increased snowmaking diversions. The source of water supply for snowmaking operations is diversions from Maroon and Castle creeks, through an agreement with the City of Aspen. These potential effects are discussed in the Cumulative Effects Section of this report.

(2) Potential increase in sediment loading due to increased amounts surface runoff (see additional discussion below, Section 4.2.2)

A higher watershed yield and associated surface runoff resulting from tree clearing and implementation of

additional snowmaking, and ground disturbance from snowmaking pipeline construction, road construction, lift construction, and terrain grading have the potential to impact water quality by increasing the amount of sediment loading in the study watersheds' drainage channels. Of particular concern are projects that involve tree clearing and terrain grading in proximity to these ephemeral channels. As outlined in Section 4.2.4, these projects will require proper design, construction, and maintenance of BMPs for erosion and sediment control in order to avoid or minimize soil erosion and subsequent transport of sediment into the drainage channels.

4.2.2 Water Quantity

The vast majority of the proposed tree cut would occur on the un-named tributaries #2 and #3 watersheds, while the proposed snowmaking addition would take place on the Spar Gulch, Tributary #1 and Tributary #2 drainage areas. **Table 15** compares the forest's acreage for baseline, existing, and proposed conditions; **Table 16** shows the proposed tree thinning by watershed; and **Table 17** displays the existing and proposed snowmaking coverage. The potential impacts to watershed resources that would result from implementation of the proposed projects are discussed in the paragraphs that follow below.

Without mitigation, the proposed projects would result in increased water yields and peak flows during the snowmelt runoff season, in all of the study watersheds. Under average conditions of precipitation and temperature, computations completed with the WRENSS model indicate that watershed yields would increase between 11 (Spar Gulch and Tributary #1) and 21 (Tributary #3) percent relative to existing conditions (see **Table 18**). This would be a direct consequence of tree removal and new snowmaking coverage. Removal of trees within the watershed reduces the amount of water intercepted, stored, and transpired by the forest; therefore an increase in water yield may be expected as a result of tree clearing. Introduction of snowmaking water into the study watersheds further increases their water yield. **Table 19** displays the computed change in runoff volumes modeled for the Proposed Action without mitigation, under average climatic conditions.

Trail grooming operations and skiing result in compacted snow; in addition, man-made snow has a higher density than natural snow (see discussion in Section 3.2.2). Typically, melt of compacted snow begins later in the season and at a slower rate as compared to natural snow. On the other hand, removal of trees to create skiing terrain often results on earlier and faster melt. Although a procedure to specifically calculate the changes in timing of melt processes due to snow compaction has not been developed, the effects of snow compaction are implicitly considered in the CSCUSA model. As shown in the plots included in **Figure 3**, timing of peak streamflows and duration of the snowmelt season resulting from the Proposed Action is not expected to substantially change as compared to existing conditions.

Table 15

Comparison of Baseline and Existing Forests vs Proposed Clear Cut Areas

Watershed	Baseline Forest (acres)	Existing Forest (acres)	Proposed Clearing (acres)	Percent of Existing
Spar Gulch	495	232	0.15	0.1%
Tributary #1	246	216	5.3	2.5%
Tributary #2	363	308	27.8	9.0%
Tributary #3	346	331	31.9	9.6%

Table 16

Comparison of Baseline and Existing Forests vs Proposed Clear Cut Areas

Watershed	Proposed Tree Thinning (acres)
Spar Gulch	0.0
Tributary #1	0.0
Tributary #2	15.3
Tributary #3	84.3

Table 17

Comparison of Existing vs Proposed Snowmaking Coverage

Watershed	Snowmaking Coverage (acres)		
	Existing	Proposed	Cumulative
Spar Gulch	81.7	29.7	111.4
Tributary #1	1.9	13.5	15.4
Tributary #2	0.0	9.6	9.6
Tributary #3	0.0	0.0	0.0

Note: Additional snowmaking coverage exists outside of the study watersheds (i.e. Pioneer Gulch and Vallejo Gulch)

Table 18

Computed Water Yield under Proposed Conditions without Mitigation

Watershed	Water Yield (AF)		Change	
	Existing	Proposed	(AF)	(%)
Spar Gulch at Summer Ditch	210.5	233.8	23.3	11%
Spar Gulch at City of Aspen	327.6	327.6	0.0	0%
Tributary #1	146.7	162.6	15.9	11%
Tributary #2	217.6	254.4	36.8	17%
Tributary #3	155.1	187.6	32.5	21%

Table 19

Computed Peak Flows under Proposed Conditions without Mitigation

Watershed	Peak Flows (cfs)		Change	
	Existing	Proposed	(cfs)	(%)
Spar Gulch at Summer Ditch	2.3	2.4	0.1	4%
Spar Gulch at City of Aspen	3.3	3.3	0.0	0%
Tributary #1	1.4	1.5	0.1	7%
Tributary #2	2.1	2.5	0.4	19%
Tributary #3	1.5	1.7	0.2	13%

A detailed report completed by J.P. McCalpin in 2010 concluded that due to historical slope stability problems on Keno Gulch, increases in the Summer Ditch flow need to be curtailed. The report states that capturing "*an equal volume of runoff to the amount of new water added to the summit area (10 million gallons), it would negate any hydrologic impacts of the summit snowmaking on slope stability (that is, it would be a "stability-neutral" action).*"[24]

> Note: the "10 million gallons" referred to by McCalpin correspond to the volume of water needed to produce snow on 34.5 acres, as estimated at the time of the report. It appears that this amount does not account for system and watershed losses.

[24] McCalpin, 2010.

McCalpin envisioned a scheme that would capture Upper Spar Gulch runoff near the Summer Road and pipe it off the mountain. At this time, however, it appears that this option is not viable. An alternative devise to accomplish the same goal of preventing the volume of runoff associated with the proposed snowmaking from discharging into Keno Gulch would consist of a hydraulic structure that would keep such volume (23.3 AF, see **Table18**) from flowing in the Summer Ditch. For example, a flow splitter box installed at the head of the Summer Ditch. Splitter boxes are simple structures commonly used in irrigation systems and water or waste water treatment plants to separate inflow into two or more directions. If properly designed, installed, and maintained, a splitter box can accurately perform the task of separating the inflow per the desired parameters. For the Upper Spar Gulch/Keno Gulch application, the WRENSS model show that under average conditions of precipitation and temperature, the proposed snowmaking would result in a runoff increase of 23.3 AF, or 11 percent relative to existing conditions. Thus, a splitter box installed where the Summer Ditch intercepts the Spar Gulch channel and designed to keep 11 percent of the annual surface runoff from entering the Summer Ditch, would effectively maintain current conditions in the Keno Gulch drainage.

The above-described proposed mitigation would result in water yield and peak flow increases for the Lower Spar Gulch watershed. The 23.3 AF of additional yield would represent a 7 percent increase as compared to existing conditions in Lower Spar Gulch and would result, on average, on an 8 percent increase of the 6-day maximum annual flow (from 3.3 to 3.55 cfs, see **Tables 20** and **Figure 3**). This in turn has the potential to negatively affect the City of Aspen's storm drainage system that receives runoff from Lower Spar Gulch. A review of the City's Surface Drainage Master Plan indicates that the storm sewer system that receives Spar Gulch runoff (System 1, Reach B on Ute Ave between Aspen Alps Rd and Original St) has a total capacity of 72 cfs.[25] The Surface Drainage Master Plan concludes that the "flow associated with snowmelt is relatively small but of long duration, and the snowmelt also conveys sediment that is deposited in the stream channels, streets, and storm sewers." The Master Plan states that the snowmelt flows and deposits are "more of a maintenance problem" as opposed to the risks of property damage and loss of life associated with mudflows and stormwater flows.

Currently, Lower Spar Gulch between approximately 250 feet below the Summer Ditch and the bottom terminal of the Bell Mountain chairlift, is drained by a channel formed in fill materials, which shows evidence of on-going erosion problems. Additionally, a service road runs parallel and in close proximity to the channel for almost its entire length. The road is constructed on a steep grade and its surface consists of loose materials that are easily transported by surface runoff into the Lower Spar Gulch channel. Most of the sediment transported by the Lower Spar Gulch flows is generated in the channel itself and from the adjacent road surface. To minimize or avoid the potential effects resulting from the increased yield and runoff peak flow, the Lower Spar Gulch channel should be improved. More specifically, the section of channel from just

[25] WRC, 2001.

below the confluence with Copper Gulch to the sediment traps by the Bell Mountain chair bottom terminal should be reconstructed as a riprap-lined feature. Riprap placed on adequate bedding and properly compacted sub-grade would eliminate or minimize channel erosion processes. Improving the road surface and installing adequately spaced road waterbars would help minimize the amount of road surface reaching the Lower Spar Gulch channel. In addition, decommissioning and re-vegetating the 1,500-foot long road between the bottom of Bell Mountain chair and Kleenex Corner would disconnect about 0.45 acres of CDA and substantially reduce the amount of sediment loading into the Lower Spar Gulch channel. These improvements would also reduce velocities of surface runoff and thus result in a decrease of Lower Spar Gulch peak flows. The sediment traps currently located next to the Bell mountain chair bottom terminal should also be improved to maximize the amount of sediment removed from the Spar Gulch flow. Additional discussion regarding proposed improvements to the drainage infrastructure is included in the following sections of this report.

Table 20

Average Volumes of Runoff under Proposed Conditions, with Mitigation

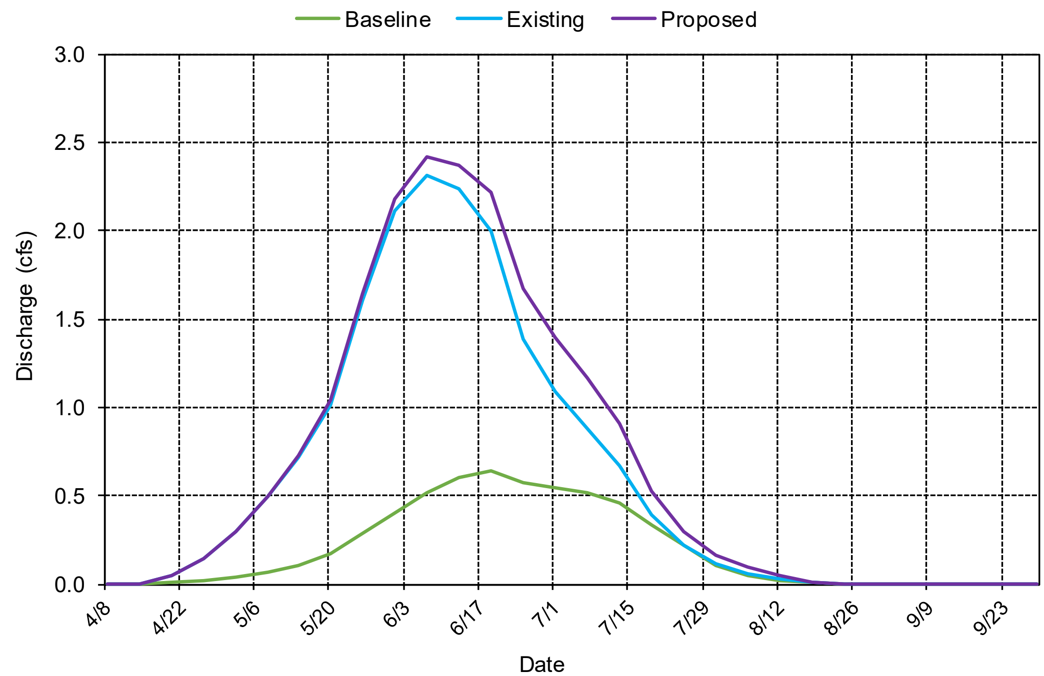
Watershed	Runoff Volume (AF)		Change	
	Existing	Proposed	(AF)	(%)
Upper Spar Gulch	210.5	233.8	23.3	11%
Summer Ditch	210.5	210.5	0.0	0%
Lower Spar Gulch	327.6	327.6	23.3	7%
Tributary #1	146.7	162.6	15.9	11%
Tributary #2	217.6	254.4	36.8	17%
Tributary #3	155.1	187.6	32.5	21%

Figure 3

Average Year Hydrographs for Baseline, Existing, and Proposed Conditions with Mitigation
(Plot does not show the effect of proposed drainage improvements that would reduce flow velocities)

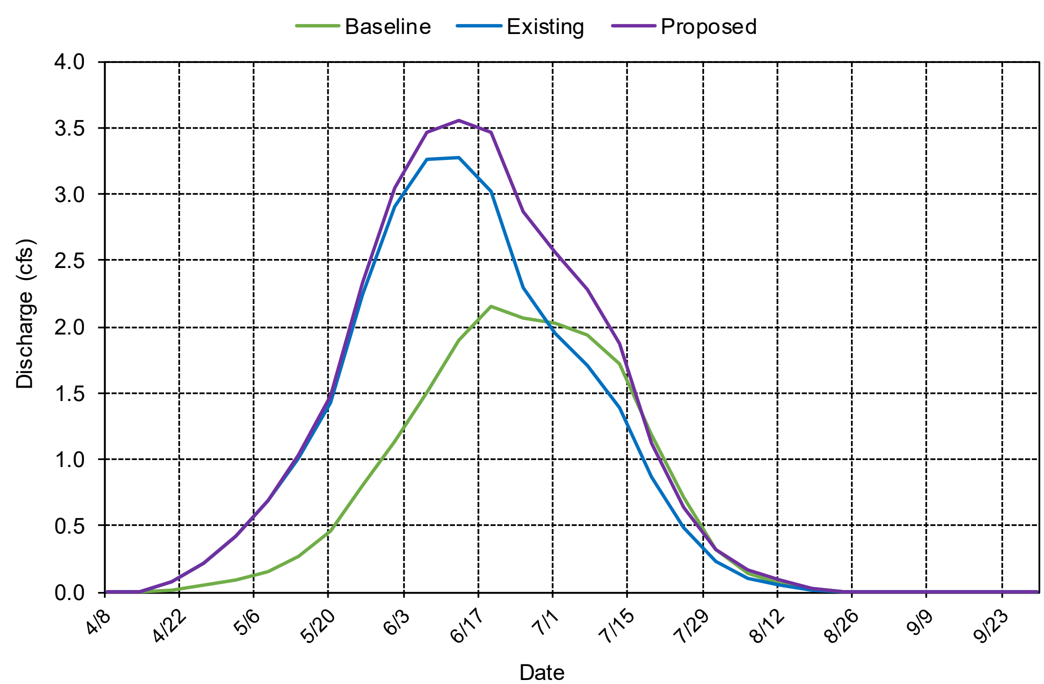
Plot 3.1

Upper Spar Gulch



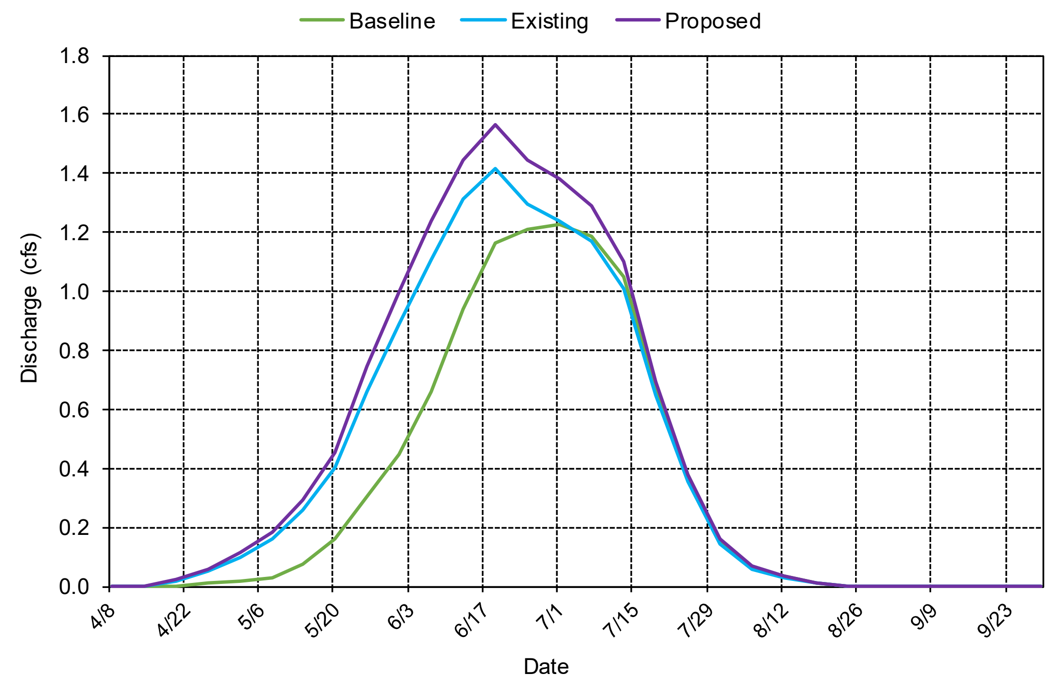
Plot 3.2

Lower Spar Gulch



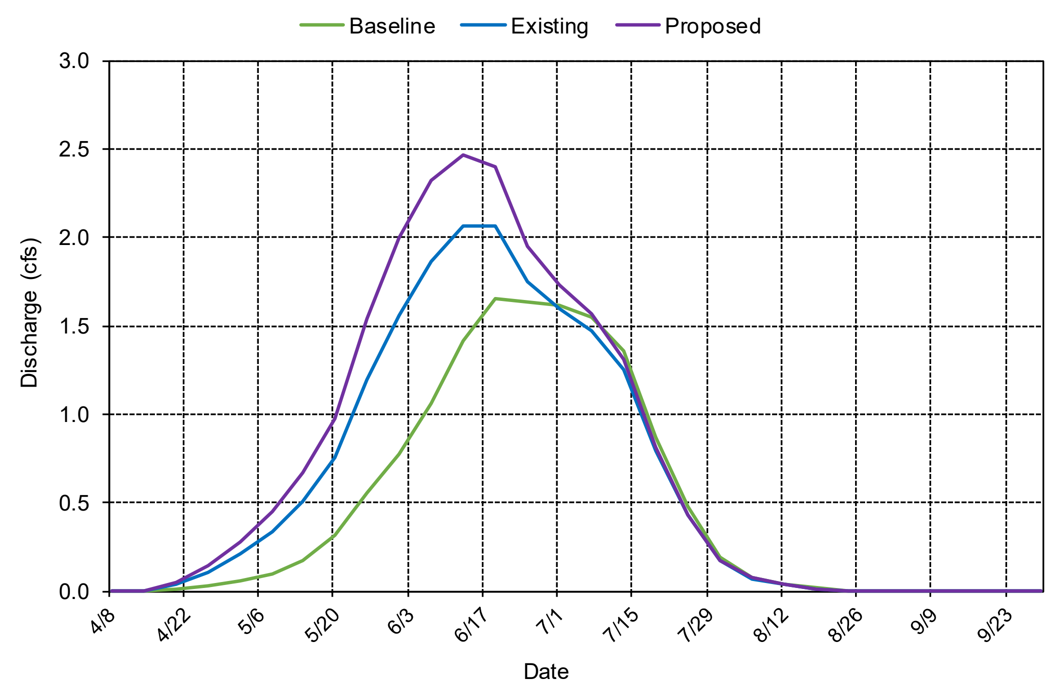
Plot 3.3

Tributary #1

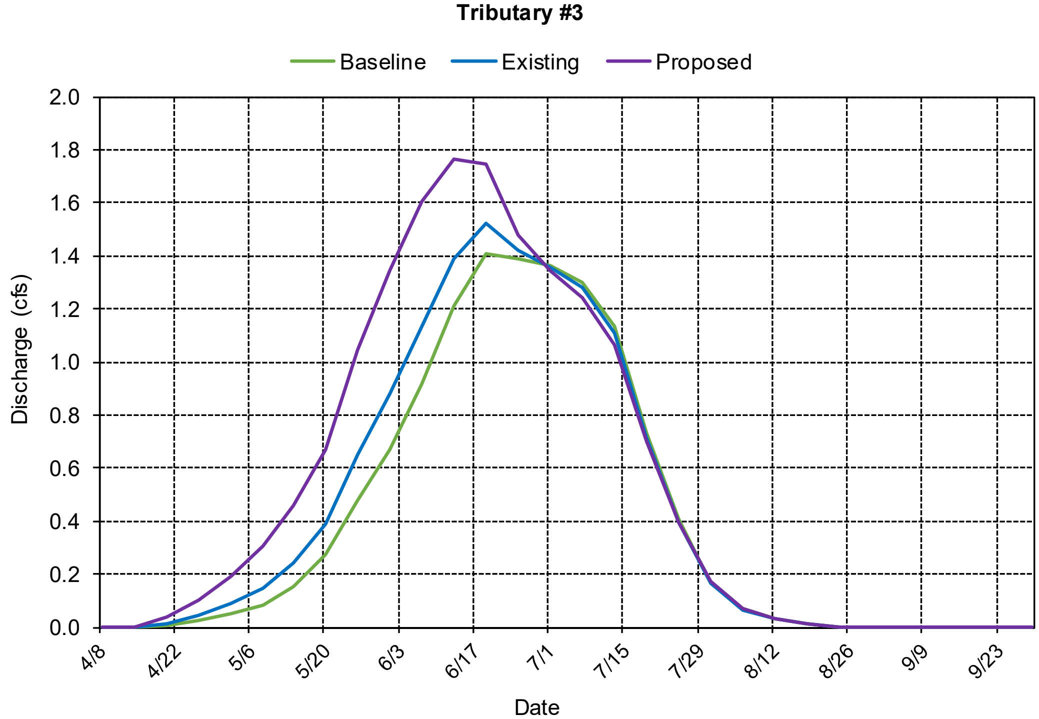


Plot 3.4

Tributary #2



Plot 3.5



4.2.3 Roads and Trails

The proposed projects include construction of a 4,300 feet road that would be needed for maintenance of the new Pandora Lift. An additional road would be also constructed to assist in the building of the Pandora Lift. This road would follow the alignment of an existing, abandoned mining/logging road that would be temporarily widened to accommodate construction vehicles. Following completion of the Pandora Lift construction, the entire length (including the 3,000-foot-long existing old mining road) would be reclaimed to original contours and revegetated.

4.2.4 Watershed Condition – Forest Plan Consistency

The proposed activities would require appropriate measures in order to “maintain or improve” stream health in accordance with the WCPH and 2002 Forest Plan Management Area 8.25 Standard 3. All projects involving terrain grading would require measures, including installation and maintenance of adequate BMPs for erosion and sediment control, in order to avoid or minimize potential negative effects to the watershed condition. Proposed measures, or Project Implementation Requirements (PIR) to be implemented with Alternative 2 projects are outlined below (these are in addition to PIR needed for protection of other resources).

PIR Common to all Projects

- Prior to implementation, submit grading plans for review and authorization by USFS. At a minimum, these documents should meet the basic requirements for stormwater permitting through the State of Colorado Stormwater Management Program.
- Prior to construction, clearly flag wetlands, tree clearing and/or grading limits.
- Avoid soil disturbing activities during periods of heavy rain or excessively wet soils.
- Make cuts, fills, and road surfaces strongly resistant to erosion (MM-9 Design Criteria).
- Drain roads, road ditches, and other disturbed areas to undisturbed soils rather than directly to streams and ephemeral channels. Drainage from disturbed areas should be modified as necessary using natural topography, rolling dips, waterbars, ditch relief culverts, etc. to achieve this goal.
- For projects involving excavation and/or grading, stockpile topsoil so that it may be used for revegetation projects.
- Ground disturbances adjacent to streams/wetlands would occur during baseflow conditions to protect water quality and minimize impacts to wetland soils/vegetation, and with sufficient time to revegetate before the winter season.
- Construction practices and operations should not introduce soils, debris, or other pollutants into streams, channels, swales, lakes, or wetlands. BMPs adequate for erosion and sediment control should be installed before ground-disturbing activities begin. If natural or biodegradable materials are not used and left on site, all non-natural and non-biodegradable materials should be removed at the end of construction.
- Grade lift terminals to drain surface runoff into well vegetated areas and away from stream channels.
- Properly compact fills (MM-11 Design Criteria).
- Where appropriate, revegetate disturbed terrain (including staging areas, log landings, skid trails, etc.) immediately after completion of grading using USFS-approved, native seeds. Install temporary BMPs for sediment and erosion control until planted vegetation provides erosion control (MM-11 Design Criteria). Monitor and manage these areas for weeds.
- Revegetation monitoring: ASC shall review with the USFS, the success of project revegetation and site restoration annually for the first five years following construction. Details of the revegetation plan shall be adjusted in response to any deficiencies identified in follow-up monitoring.
- Areas compacted by construction activities may require mechanical subsoiling or scarification to the compacted depth to reduce bulk density and restore porosity.

- Where possible, utilize existing roads and trails to access construction sites.

- To the extent possible, avoid operating heavy equipment on slopes steeper than 30 percent.

PIR for Construction of Proposed Mountain Roads

- Design road ditches and cross drains to limit flow to ditch capacity and prevent erosion and failure (MM-10 Design Criteria). Install road-relief culverts or road waterbars at a spacing adequate for the road slope and ditch characteristics (MM-10 Design Criteria). Adhere to USFS guidelines for recommended spacing between relief culverts.

- Design, implement, and maintain standard sediment control BMPs (e.g., sediment traps) at the discharge of road-side ditches and culverts. Where possible, discharge runoff into well vegetated areas, away from ephemeral and intermittent channels.

- Construct roads to avoid down-road flow and ponding by cross sloping road surface 2 to 4 percent. Out-slope cross sections of service roads.

- Inspect and maintain BMPs a minimum of twice annually: (1) in the spring, as soon as conditions allow; and (2) in the fall season, before snow covers the ground.

PIR for Management of Snowmelt Runoff

<u>Upper Spar Gulch</u>

Implementation of the proposed projects would result in increased volumes and rates of runoff in all of the study watersheds. As shown in **Table 18**, implementing the proposed projects without mitigation would result in a water yield increase of approximately 23.3 AF at a point where the Spar Gulch channel is intercepted by the Summer Ditch. As discussed in Section 4.2.2, due to past slope instability events in Keno Gulch, where the Summer Ditch discharges its flow, PIRs should be implemented to prevent the "runoff from new summit snowmaking from increasing the flow in the Summer Ditch and into Keno Gulch."[26] In addition, evidence of channel erosion has been observed in the Upper Spar Gulch drainage. For instance, an eroded gully has formed on the lower elevations of the Dipsy Doodle ski trail, just above the Summer Road (County Road 14), see **Photos 6-7**. Additional erosion problems (lateral and vertical) exist along the Upper Spar Gulch drainage down-slope from the Summer Road. More specifically, where the channel runs along the western edge of Bell Mountain's base, near the Lift 3 bottom terminal (see **Photos 8-9**).

- Repair eroded channel that formed on Dipsy Doodle. For example, construct a sinuous riprap-lined channel at this location to collect and convey surface runoff (see example shown in **Photo 10**).

- Construct waterbars, where feasible, along the existing ski trails within the Upper Spar Gulch

[26] McCalpin, 2010.

watershed. Discharge waterbars, through adequate BMPs for erosion control, into well vegetated areas.

- Improve the road-side ditch that drains the Summer Road near Pump House Hill. Lining the ditch with riprap and/or installing rock check dams along the ditch would slow down flow velocities and minimize erosion.
- Install grade controls or other measures to prevent erosion of the Spar Gulch channel between the Summer Road and the Summer Ditch diversion.
- Install BMPs for erosion control at the outlet of existing culverts along Spar Gulch, upstream from the Summer Ditch.
- Install a splitter box just upstream from the Summer Ditch diversion point, to help maintain current volumes of runoff diverted towards Keno Gulch. For example, the WRENSS model shows that, on average, the volume of runoff in the Upper Spar Gulch watershed would increase by 11 percent. A splitter box designed to divert approximately 89 percent of the surface runoff into the Summer Ditch would help accomplish this goal. The remaining 11 percent of runoff would flow down in the Lower Spar Gulch drainage.

Implementation of the PIRs outlined above would minimize the negative effects of the snowmaking proposed in the Upper Spar Gulch watershed. The PIRs would reduce flow velocities in the drainage and provide opportunities for infiltration of snowmelt.

Photo 6
View of the eroded channel that formed on the Dipsy Doodle trail (view from the Summer Road)

Photo 7
Close up view of the Dipsy Doodle trail eroded channel

Photo 8
Headcutting on Spar Gulch channel, near Pump House Hill and Deer Park

Photo 9
Spar Gulch channel erosion, near Lift 3 bottom terminal

Photo 10
Example of a riprap-lined channel constructed on a Colorado ski area trail

Lower Spar Gulch

A site-specific drainage management plan was outside the scope of work associated with this report. However, opportunities to improve drainage conditions on the Lower Spar Gulch watershed were identified by RESOURCE during site visits in May, July and August of 2018. The Spar Gulch channel below Summer Ditch is steep and eroded on fill materials. Currently, artificial snow is made on the trail adjacent to the channel. In addition, a road exists parallel to the Spar Gulch channel, from the bottom terminal of Lift 3 to the bottom of Lift 5. This road is also steep, not properly compacted, and BMPs for erosion and sediment control are minimal. As a consequence, surface runoff velocities are relatively high which results in damage to the road surface (ruts and rill erosion), and a substantial supply of sediment to the Spar Gulch channel (see additional discussion under Section 4.2.2 and **Photos 11-13**).

Based on these field observations, it appears that much of the sediment carried by Lower Spar Gulch is generated along the 1,500-foot stretch between Kleenex Corner and the bottom of Bell Mountain lift. In this area, the Lower Spar Gulch channel shows evidence of on-going erosion problems such as head-cutting, channel widening and down-cutting. In addition, surface runoff on the un-vegetated trail surface causes rill and gully erosion.

- To improve current drainage conditions and avoid worsening existing erosion problems due to the 11 percent increase in runoff volume that would result from the proposed projects, RESOURCE recommends that the Spar Gulch channel below the confluence with Copper Gulch, compacted and lined with riprap (angular rock of adequate size is available on-site). It is important that the channel is properly bedded and compacted before the riprap is placed, to prevent Spar Gulch runoff from eroding flow paths underneath the rock.
- Rock check dams should be installed along the Spar Gulch channel at adequate spacing according to the channel slope.
- The Spar Gulch trail surface adjacent to the channel should also be improved. At a minimum, construct waterbars, and improve the existing ones, to deflect surface runoff from the trail surface into the Spar Gulch channel; properly space waterbars according to the trail slope. In addition, RESOURCE recommends that all or a portion of the 20-foot wide Spar Gulch trail below Kleenex Corner is decommissioned and re-vegetated.
- Improve the four sediment traps that currently exist adjacent to the Lift 5 bottom terminal, to maximize the amount of sediment that can be detained and help reduce flow velocities downstream of these structures.

The proposed improvements to the Lower Spar Gulch trail and channel would result in a drastic reduction of the sediment loading into Spar Gulch runoff. Furthermore, the estimated 11 percent increase in Upper Spar Gulch runoff volume would not result in increased rates of flow in the Lower Spar Gulch channel

because typically snowmelt in the Upper Spar Gulch watershed occurs 2-3 weeks after flows in the Lower Spar Gulch drainage have peaked. Therefore, the proposed Summit Snowmaking projects are not expected to negatively impact drainage in the Lower Spar Gulch watershed if implemented with the recommended improvements.

Photo 11
View of Spar Gulch road below Kleenex Corner.
Note loose road materials and ruts on the road.

Photo 12
Spar Gulch road culvert blocked with road sediments.

Photo 13
Spar Gulch channel erosion upstream from Lift 5 bottom terminal.

Tributaries #1 and #2

Approximately 13.5 acres of the 53 acres of proposed snowmaking would be implemented in the Tributary #1 drainage area, up-gradient from the proposed Gents #2 and #3 snowmaking ponds. Together with the existing Gents Pond #1, the total storage capacity of the ponds would be 26.9 AF. The volume of additional runoff that would result from implementation of the Proposed Action would be, on average, 15.9 AF for the Tributary #1 watershed. An unknown portion of this volume would infiltrate into the ground; the surface runoff component, however, would flow towards the ponds. However, the gentle slopes up-gradient of the ponds' site would likely contribute to additional dissipation and infiltration of surface runoff before it reaches the ponds.

In addition, a portion of the surface runoff originating in the adjacent Tributary #2 watershed (including the trails where new snowmaking coverage is proposed for this watershed) is intercepted by the existing road drainage ditch and discharged onto trails that drain towards the snowmaking ponds. In order to properly manage surface runoff, the existing drainage features along the upper sections of County Road 14 need to be improved. For example, some road culverts are partially blocked with sediment (see **Photo 14**) and road ditches and waterbars discharge directly onto the slopes (**Photo 15-17**).

- Improve road-side ditch along the upper sections of the County Road 14 and on the Loushin Road that intercept snowmelt runoff originating from trails where new snowmaking coverage is proposed.
- Install relief culverts along road-side ditches at spacing adequate to the road gradient.

- Design and install adequate BMPs for erosion and sediment control on all road culverts and waterbars.
- Implement a BMP maintenance program, to inspect, clean and repair or replace BMPs for erosion and sediment control, at least twice annually: as soon as snowmelt conditions allow; and at the end of the summer, before snow covers the ground.
- Evaluate construction of ski trail waterbars on trails where snowmaking is proposed.
- Following implementation of the proposed snowmaking, inspect ski trails where man-made snow applications occur during the snowmelt season to determine if BMPs are functioning as designed, or if additional BMPs are needed.

Construction and implementation of the Proposed Action following the PIRs outlined above will maintain or improve the overall condition of the study watersheds and, therefore be consistent with the WCPH and Forest Plan standards and will not adversely impact the condition of study watersheds.

Photo 14
County Road 14 (Summer Road) culverts partially blocked with sediment.

Photos 15, 16, and 17
County Road 14 (Summer Road) ditch relief discharges directly
onto the ski trail, causing rill and gully erosion on the slopes.

Photo 16
Rill and gully erosion at the discharge of road culvert.

Photo 17
Rill and gully erosion on ski slope below discharge of road culvert.

5.0 CUMULATIVE EFFECTS

5.1 SCOPE OF THE ANALYSIS

5.1.1 Temporal Bounds

Temporal extents of the analysis begins with pre-development conditions at Aspen Mountain, extending through the history of the Resort to the present, and includes the lifespan of currently proposed projects as well as those that are reasonably foreseeable future actions, in general ten to twenty years into the future from the date of this report.

5.1.2 Spatial Bounds

The effects on watershed condition that would result from implementation of the Proposed Action would be most evident in the study watersheds immediately downstream of the project area. The study watersheds are tributary to the Roaring Fork River, where the effects of changes in flow are negligible relative to the hydrology of this larger watershed. Because the source of supply for snowmaking operations are the Marron and Castle creeks, the downstream spatial boundary for the cumulative effects analysis is defined at a point immediately downstream from the confluence of Maroon Creek and the Roaring Fork River. The area draining to this point totals 33,182 acres. The attached **Figure A-3** displays the cumulative effects spatial boundary.

5.2 CUMULATIVE EFFECTS ANALYSIS

5.2.1 Alternative 1

The WRNF has completed an assessment of its watersheds following the USFS Watershed Condition Framework Implementation Guide.[27] The assessment rated watersheds at the 12-th HUC level. Three 12-th level watersheds are included in the cumulative effects analysis area:

(1) The Roaring Fork River above Aspen, 12-th level Hydrologic Unit Code (HUC12: 140100040106);

(2) The Outlet Castle Creek, HUC12: 140100040203; and

(3) The Willow Creek-Maroon Creek, HUC12: 140100040302

The Roaring Fork River above Aspen watershed was classified as "Functioning Properly", while the Outlet Castle Creek and the Willow Creek-Maroon Creek basin were determined to be "Functioning at Risk". Twelve indicators of watershed condition were examined and rated by the WRNF for the assessment. **Table 21** summarizes the ratings given to each indicator.

Under the No Action Alternative, ASC would continue its current summer and winter operations. Removal of vegetation, terrain grading, and/or implementation of additional snowmaking would not result from selection of this alternative. It is anticipated that the existing activities on private and NFS lands would continue to require management to minimize potential impact to the project area watersheds. Future implementation of projects would require site-specific studies and impacts to water resources would be minimized to the extent practicable.

[27] USDA Forest Service, 2011a.

Table 21

Summary of Watershed Condition Indicators

Indicator	Roaring Fork River above Aspen	Outlet Castle Creek	Willow Creek-Maroon Creek
Aquatic Biota	Poor	Poor	Poor
Riparian/Wetland Vegetation	Good	Good	Good
Water Quality	Good	Good	Good
Water Quantity	Fair	Fair	Poor
Aquatic Habitat	Good	Fair	Fair
Roads and Trails	Fair	Poor	Poor
Soils	Good	Good	Good
Fire Regime	Good	Good	Fair
Forest Cover	Good	Good	Good
Forest Health	Good	Good	Good
Rangeland Vegetation	Good	Good	Good
Terrestrial Invasive Species	Good	Good	Good

5.3.2 Alternative 2

Water Quality

Because there are no impacts to water quality anticipated from any of the project components proposed in Alternative 2 (see Section 4.2.1), there would be no cumulative impacts to water quality.

Snowmaking Water

An assessment of historic snowmaking water use at ASC over the most recent 5-year period shows that Aspen Mountain utilizes, on average 184.1 AF of water per season for snowmaking purposes. This yields an average ratio of 1.07 AF of snowmaking diversions per treated acre. Based upon this ratio, the 53 acres of new snowmaking coverage would require approximately 56.7 AF of additional water diversions (53x1.07 = 56.7). With the additional 53 acres of snowmaking proposed under Alternative 2, the total surface area of ski trails with snowmaking coverage would reach 225 acres, and the water diversions would increase to 240.8 AF.

Aspen Mountain's snowmaking primary pump station is located at the base of the mountain and draws its

water supply from the City of Aspen's municipal system, per the terms and conditions of the existing water supply agreement between the City and ASC. It is expected that the water supply necessary to support the proposed snowmaking will also be provided by the City. The City's primary source of supply originates from direct flow diversions on Castle Creek and Maroon Creek, which currently provide water for municipal uses, including snowmaking.

Of the total water diverted for snowmaking purposes, between 2.5 and 12.5 percent is lost to evaporation and sublimation during production of artificial snow. This "initial loss" increases with the air temperature present at the time of man-made snow production. Additional water losses occur during the following spring and summer months, again through evaporation and sublimation processes but also as evapotranspiration by vegetation in the vicinity of trails where snowmaking occurred. For the average conditions of temperature and precipitation typically present at Aspen Mountain, total losses amount to approximately 26%; the balance is available as surface runoff and shallow groundwater to the receiving waters (the Roaring Fork River). Therefore, typical depletions due to snowmaking water uses under existing conditions total 47.9 acre-feet (184.1 x 0.26). Depletions associated with the Proposed Action would amount to 14.7 acre-feet (56.7 x 0.26). **Table 22** summarizes the coverage, diversions, and depletions under existing and proposed conditions.

Table 22

Summary of Snowmaking Coverage and Water Demands

Snowmaking Parameter	Existing	Proposed	TOTAL
Coverage (acres)	172.0	53.0	225.0
Diversions (AF)	184.1	56.7	240.8
Depletions (AF)	47.9	14.7	62.6

Instream Flows

Instream flows are non-consumptive, in-channel water rights owned by the Colorado Water Conservation Board (CWCB) and administered within the State of Colorado water right priority system with the purpose of preserving or improving the natural environment to a reasonable degree. Instream flows for the segment of the Castle Creek where the City's diversion is located were decreed at 12.0 cfs. Similarly, the instream flow downstream from the City's diversion on Maroon Creek is 14.0 cfs. A recent study by RESOURCE concluded that, under current hydrological conditions, streamflows in Maroon and Castle creeks are sufficient to support the CWCB instream flows and the City's municipal and snowmaking water demands.[28] Even under future drought conditions, streamflows in Maroon and Castle creeks are expected to exceed

[28] Resource Engineering, 2018.

the instream flows, and municipal and snowmaking demands. Assuming that the City of Aspen would continue its longstanding policy of allowing for bypass flows below its headgates at all times to help maintain the instream flows, the study warns that during the peak snowmaking month of December, streamflows in excess of future projected demands are small, indicating that some snowmaking shortages are possible under drought conditions.

Watershed Condition

The proposed tree removal, snowmaking applications and associated increases in watershed yield and peak streamflows discussed in Section 4.2 would not have a measurable effect at the cumulative effects scale. Despite direct project effects of the Proposed Action, when considered cumulatively, in addition to past, present, and reasonably foreseeable future actions, implementation of Alternative 2 would maintain stream health and watershed condition through successful implementation of PIRs described in Section 4 of this report. By maintaining the health of the study watersheds, Alternative 2 would not exhibit a negative influence upon watershed conditions in a cumulative context.

6.0 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

The Forest Service Handbook 1909.15 provides the following definitions relevant to this analysis:[29]

> Irretrievable: A term that applies to the loss of production, harvest, or use of natural resources. For example, some or all of the timber production from an area is lost irretrievably while an area is serving as a winter sports site. The production lost is irretrievable, but the action is not irreversible. If the use changes, it is possible to resume timber production.
>
> Irreversible: A term that describes the loss of future options. Applies primarily to the effects of use of nonrenewable resources, such as minerals or cultural resources, or to those factors, such as soil productivity that are renewable only over long periods of time.

6.1 ALTERNATIVE 1

The No Action Alternative would result in no additional commitment of resources on NFS lands.

6.2 ALTERNATIVE 2

Tree removal, terrain grading, and additional snowmaking applications on private and NFS lands would result from implementation of the projects proposed under Alternative 2, as discussed in detail in Section 4 of this report. Irretrievable loss of production and harvest of the silvicultural resource within the SUP boundary, occurs from its designation as Management Area 1B, Downhill Skiing and Winter Sports. As stated in the "Irretrievable" definition, above, this loss is not irreversible. The Proposed Action would not change or add to this existing irretrievable loss. The additional 56.7 AF of water diversions from the Maroon

[29] USDA Forest Service, 2011b.

and Castle creeks that would be required for production of man-made snow as proposed under Alternative 2, would result in 14.7 AF of new irretrievable loss of the water resource. However, these losses are not irreversible, since the stream water is a renewable resource and changing the activity (in this case, snowmaking operations) would reduce or stop the loss. Irreversible impacts to stream health and water quality are not expected to occur as a consequence of implementation of Alternative 2 projects. The Proposed Action includes PIRs that would maintain or improve the condition of the study watersheds.

Respectfully Submitted,

RESOURCE ENGINEERING, INC.

Raul Passerini, P.E.
Water Resources Engineer

RP/rp
File: 563-5.8

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ATTACHMENT A

REPORT FIGURES

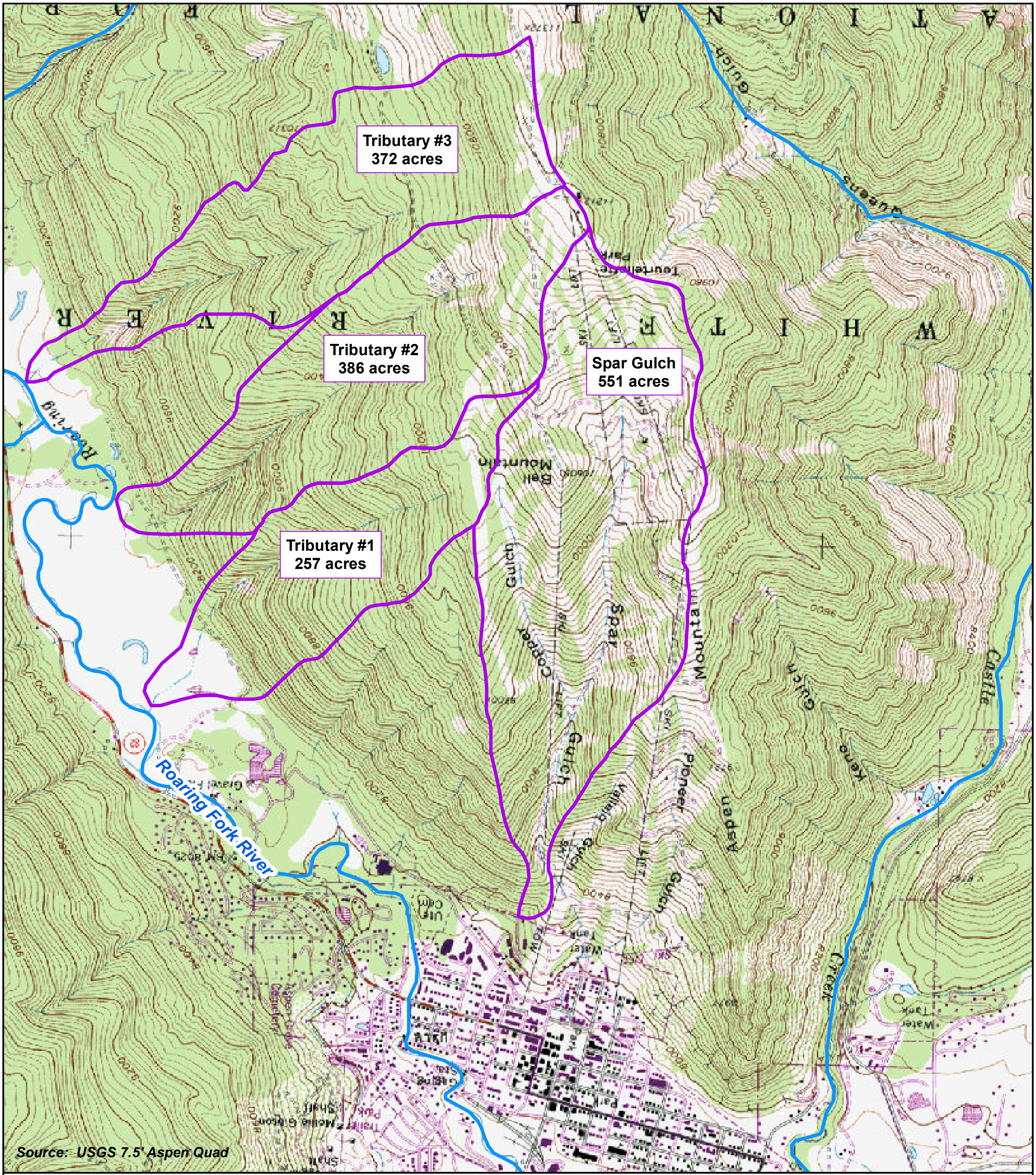

Figure A-1
Aspen Mountain
Study Watersheds Map

RESOURCE
ENGINEERING, INC.
909 Colorado Avenue / Glenwood Springs, CO 81601
Voice: (970) 945-6777 - Web: www.resource-eng.com

1 in = 2,000 feet

0 750 1,500 3,000 Feet

Date: 8/20/2018
File: 563-5.8
Drawn: RP
Approved:

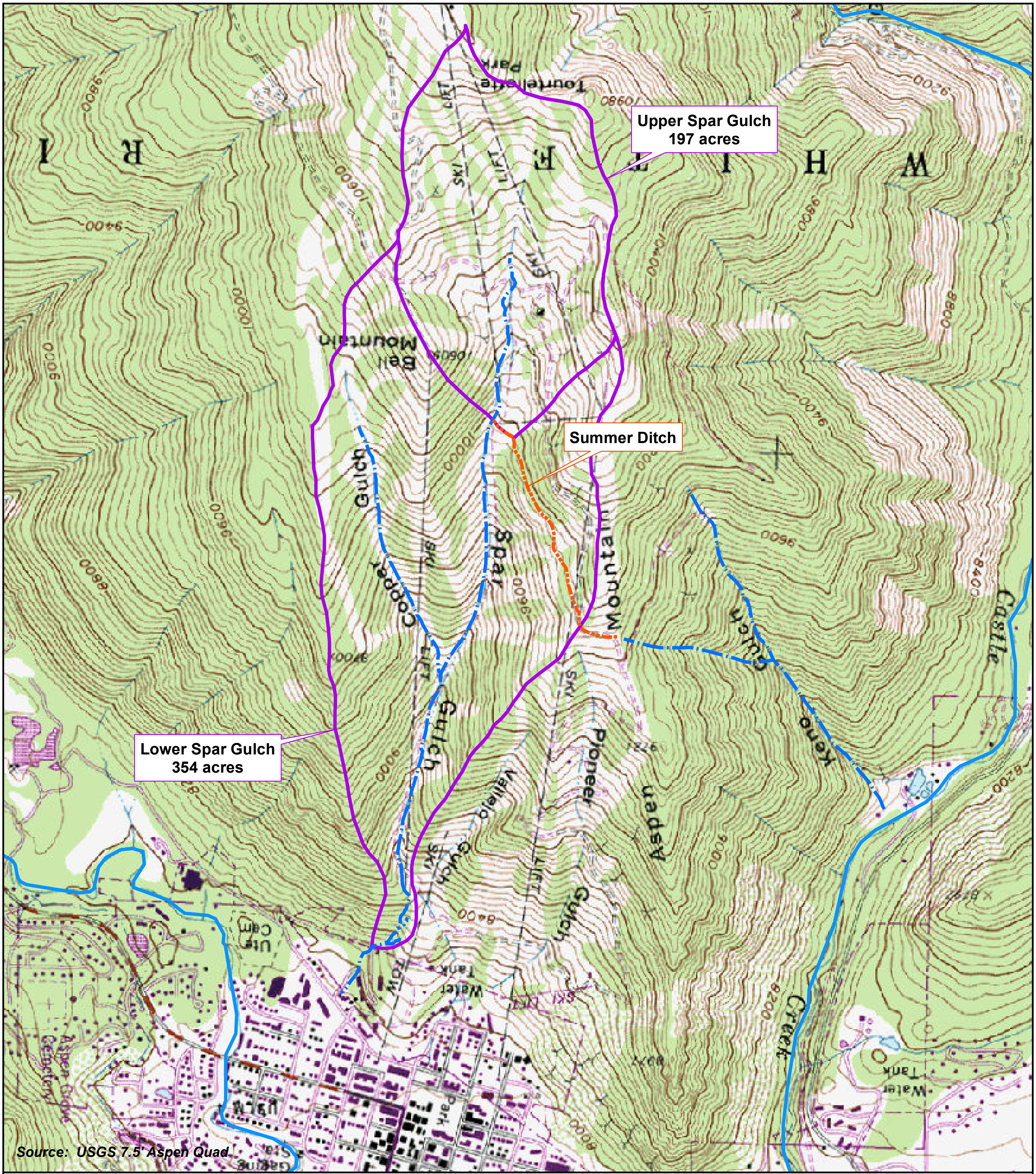

Figure A-2
Aspen Mountain
Spar Gulch Watershed Map

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File: 563-5.8
Drawn: RP
Approved:

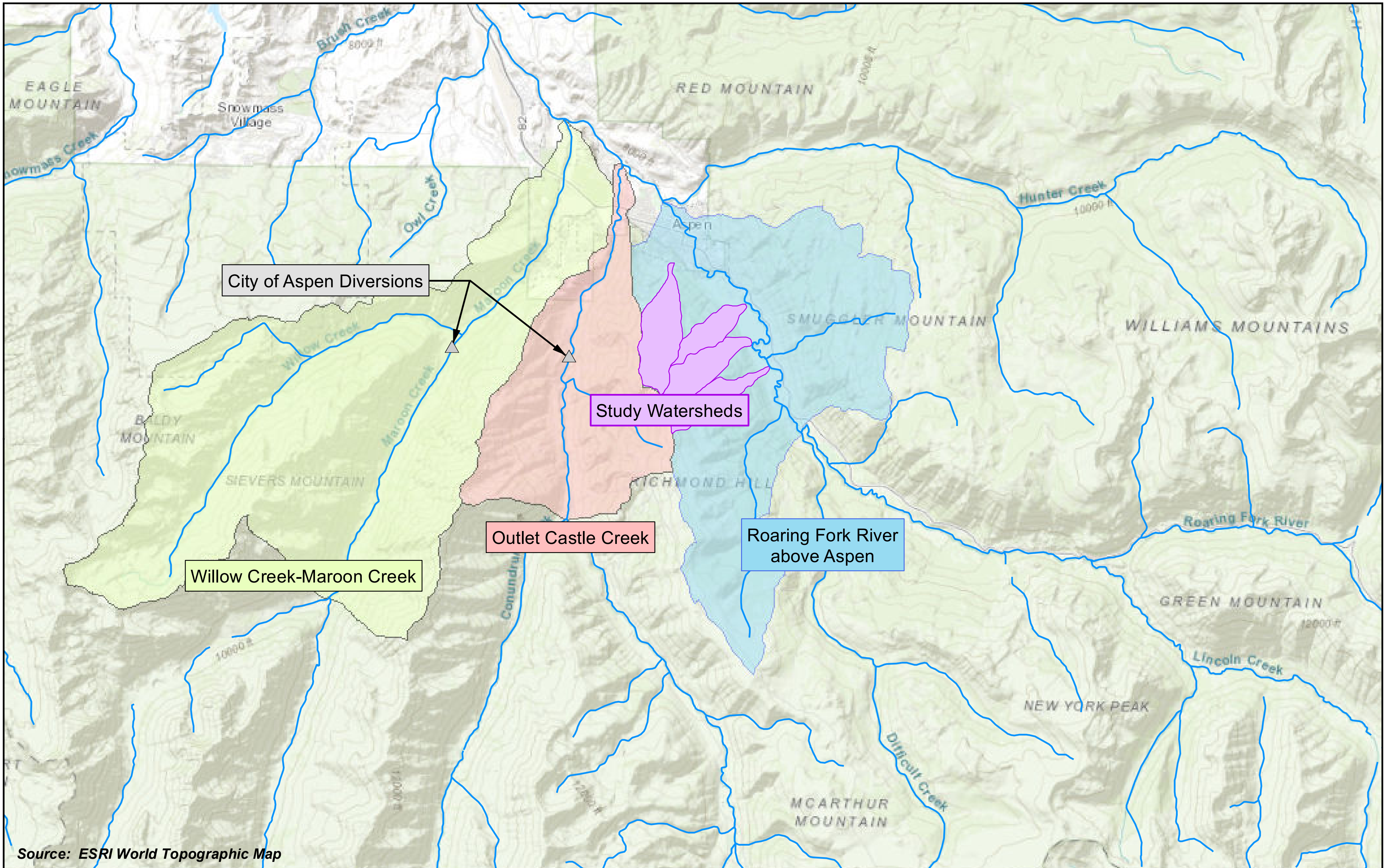

Figure A-3
Aspen Mountain
Cumulative Effects Watersheds Map

RESOURCE ENGINEERING, INC.
909 Colorado Avenue / Glenwood Springs, CO 81601
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1 in = 2 miles

0 1 2 4 Miles

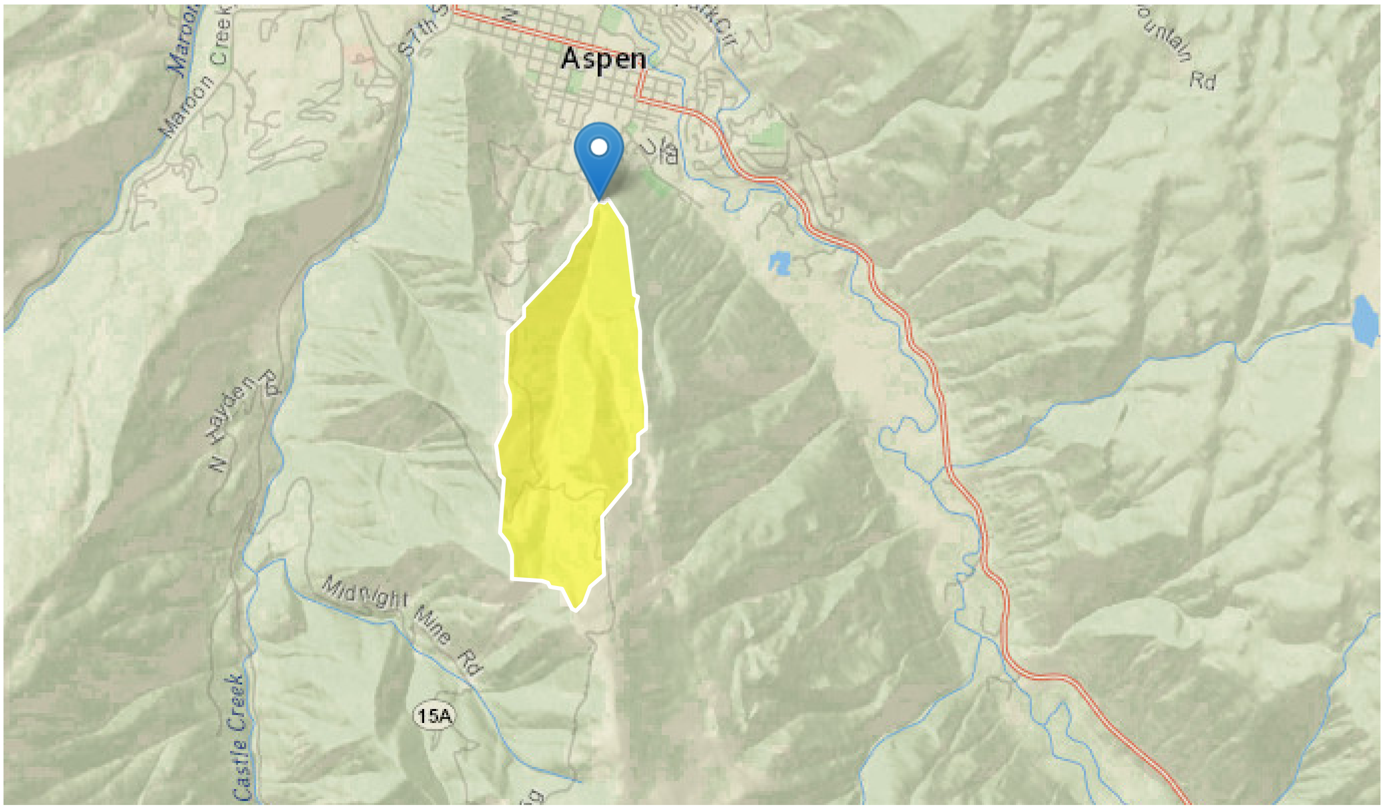
Date: 2018-08-29
File: 563-5.8
Drawn: RP
Approved:

APPENDIX A

StreamStats Report for Spar Gulch

Spar Gulch StreamStats Report

Region ID: CO
Workspace ID: CO20181030181522942000
Clicked Point (Latitude, Longitude): 39.18048, -106.81865
Time: 2018-10-30 12:15:37 -0600



Includes Upper Spar Gulch (i.e. dismisses Summer Ditch)

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	0.86	square miles
PRECIP	Mean Annual Precipitation	26.22	inches
ELEV	Mean Basin Elevation	10029	feet
BSLDEM10M	Mean basin slope computed from 10 m DEM	44.7	percent

Flow-Duration Statistics Parameters [Mountain Region Flow Duration]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.86	square miles	1	1060
PRECIP	Mean Annual Precipitation	26.22	inches	18	47

Flow-Duration Statistics Disclaimers [Mountain Region Flow Duration]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Flow-Duration Statistics Flow Report [Mountain Region Flow Duration]

Statistic	Value	Unit
10 Percent Duration	2.83	ft^3/s
25 Percent Duration	0.632	ft^3/s
50 Percent Duration	0.229	ft^3/s
75 Percent Duration	0.117	ft^3/s
90 Percent Duration	0.0529	ft^3/s

Flow-Duration Statistics Citations

Capesius, J.P., and Stephens, V. C.,2009, Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136, 32 p. (http://pubs.usgs.gov/sir/2009/5136/http://pubs.usgs.gov/sir/2009/5136/)

Flood-Volume Statistics Parameters [Mountain Region Max Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.86	square miles	1	1060
PRECIP	Mean Annual Precipitation	26.22	inches	18	47

Flood-Volume Statistics Disclaimers [Mountain Region Max Flow]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Flood-Volume Statistics Flow Report [Mountain Region Max Flow]

Statistic	Value	Unit
7 Day 2 Year Maximum	8.07	ft^3/s
7 Day 10 Year Maximum	12.3	ft^3/s
7 Day 50 Year Maximum	17	ft^3/s

Flood-Volume Statistics Citations

Capesius, J.P., and Stephens, V. C.,2009, Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136, 32 p. (http://pubs.usgs.gov/sir/2009/5136/http://pubs.usgs.gov/sir/2009/5136/)

Monthly Flow Statistics Parameters [Mountain Region Mean Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.86	square miles	1	1060
PRECIP	Mean Annual Precipitation	26.22	inches	18	47

Monthly Flow Statistics Disclaimers [Mountain Region Mean Flow]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Monthly Flow Statistics Flow Report [Mountain Region Mean Flow]

Statistic	Value	Unit
January Mean Flow	0.13	ft^3/s
February Mean Flow	0.121	ft^3/s
March Mean Flow	0.119	ft^3/s
April Mean Flow	0.2	ft^3/s
May Mean Flow	2.41	ft^3/s
June Mean Flow	6.5	ft^3/s
July Mean Flow	2.03	ft^3/s
August Mean Flow	0.839	ft^3/s
September Mean Flow	0.417	ft^3/s
October Mean Flow	0.285	ft^3/s

Statistic	Value	Unit
November Mean Flow	0.209	ft^3/s
December Mean Flow	0.155	ft^3/s

Monthly Flow Statistics Citations

Capesius, J.P., and Stephens, V. C.,2009, Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136, 32 p. (http://pubs.usgs.gov/sir/2009/5136/http://pubs.usgs.gov/sir/2009/5136/)

Annual Flow Statistics Parameters [Mountain Region Mean Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.86	square miles	1	1060
PRECIP	Mean Annual Precipitation	26.22	inches	18	47

Annual Flow Statistics Disclaimers [Mountain Region Mean Flow]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Annual Flow Statistics Flow Report [Mountain Region Mean Flow]

Statistic	Value	Unit
Mean Annual Flow	1.14	ft^3/s

Annual Flow Statistics Citations

Capesius, J.P., and Stephens, V. C.,2009, Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136, 32 p. (http://pubs.usgs.gov/sir/2009/5136/http://pubs.usgs.gov/sir/2009/5136/)

Low-Flow Statistics Parameters [Mountain Region Min Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.86	square miles	1	1060
PRECIP	Mean Annual Precipitation	26.22	inches	18	47

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
ELEV	Mean Basin Elevation	10029	feet	8600	12000

Low-Flow Statistics Disclaimers [Mountain Region Min Flow]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Low-Flow Statistics Flow Report [Mountain Region Min Flow]

Statistic	Value	Unit
7 Day 2 Year Low Flow	0.0364	ft^3/s
7 Day 10 Year Low Flow	0.0145	ft^3/s
7 Day 50 Year Low Flow	0.0176	ft^3/s

Low-Flow Statistics Citations

Capesius, J.P., and Stephens, V. C.,2009, Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136, 32 p. (http://pubs.usgs.gov/sir/2009/5136/http://pubs.usgs.gov/sir/2009/5136/)

Peak-Flow Statistics Parameters [Mountain Region Peak Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.86	square miles	1	1060
BSLDEM10M	Mean Basin Slope from 10m DEM	44.7	percent	7.6	60.2
PRECIP	Mean Annual Precipitation	26.22	inches	18	47

Peak-Flow Statistics Disclaimers [Mountain Region Peak Flow]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Peak-Flow Statistics Flow Report [Mountain Region Peak Flow]

Statistic	Value	Unit

Statistic	Value	Unit
2 Year Peak Flood	14.4	ft^3/s
5 Year Peak Flood	21.3	ft^3/s
10 Year Peak Flood	25.5	ft^3/s
25 Year Peak Flood	32.6	ft^3/s
50 Year Peak Flood	39.1	ft^3/s
100 Year Peak Flood	43.4	ft^3/s
200 Year Peak Flood	47.1	ft^3/s
500 Year Peak Flood	57.1	ft^3/s

Peak-Flow Statistics Citations

Capesius, J.P., and Stephens, V. C.,2009, Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136, 32 p. (http://pubs.usgs.gov/sir/2009/5136/http://pubs.usgs.gov/sir/2009/5136/)

Application Version: 4.2.1